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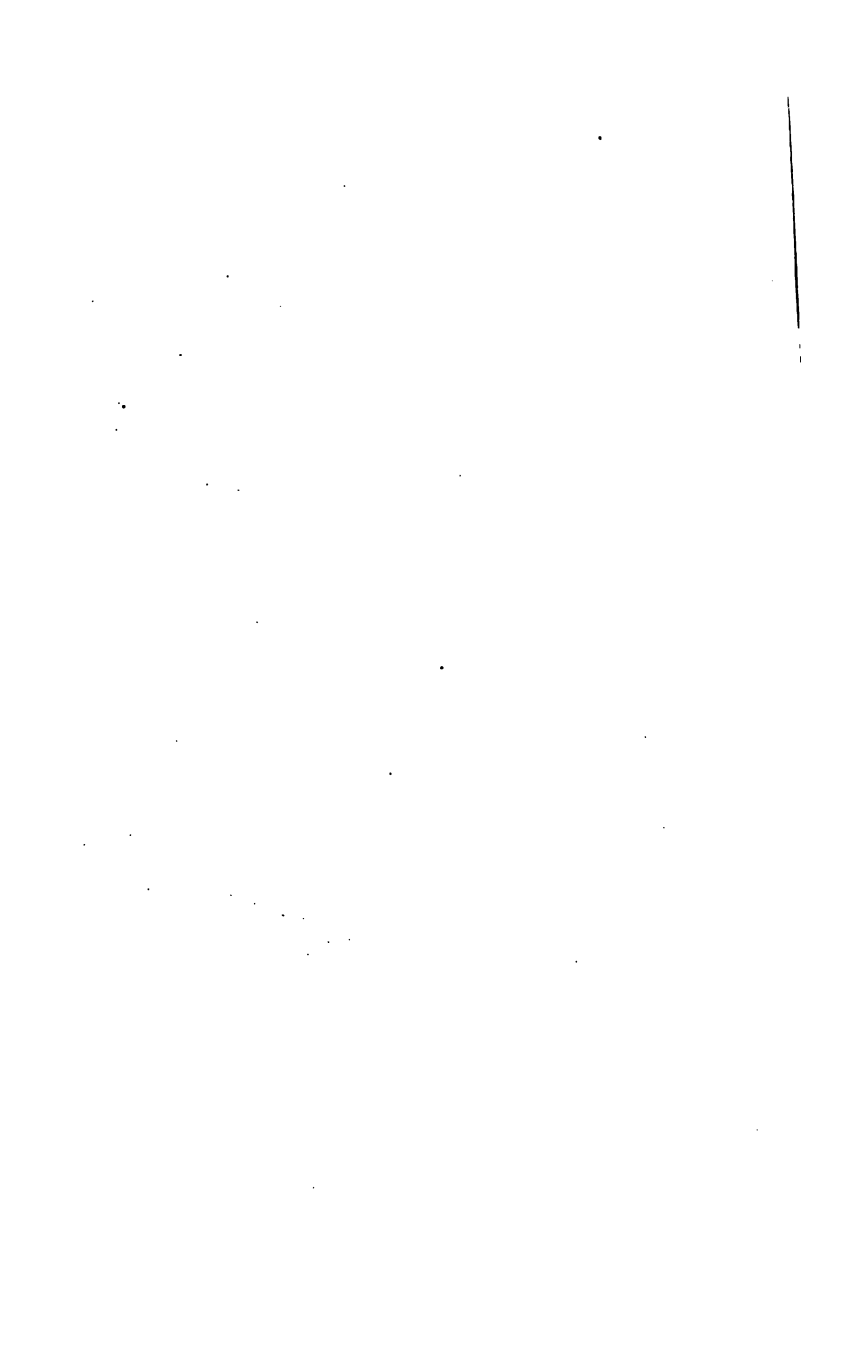
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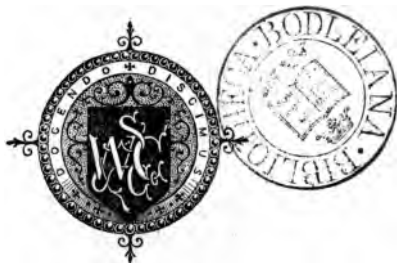
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## P R E F A C E.

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THE study of Minerals, although of the utmost importance to many thousands of our countrymen, and especially to the very numerous and intelligent class of metal-miners, has been until lately almost entirely confined to a few students in the Universities of Cambridge, Edinburgh, and Dublin. Some of these students have made for themselves a European reputation, more especially in the department of crystallography; but the working miner has usually been content to know only the two or three common forms of the ores for which he more especially labours; and the result of this ignorance has been seen in many expensive mistakes—of pyrites for gold, quartz for diamonds or other precious stones, etc., or in the waste of many valuable minerals of unobtrusive exterior.

Much of this ignorance of Minerals among the working miners has been owing to the want of teachers; much to the abstruse nature of the text-books, which have been mostly written for students possessing a considerable knowledge of Mathematics, and which have laid undue stress upon forms of rare occurrence.



Within the last few years the Royal School of Mines, the patient labours of a few isolated and self-taught students, and especially the classes of the Miners' Association of Cornwall and Devon, have to some extent supplied the lack of teachers : and the want of suitable books, except for very elementary students, has been met by the publication of several excellent mineralogical works, both English and American. It is hoped that this little work, which embodies the five years' experience of its author in teaching the elements of Mineralogy to students whose mathematical knowledge very rarely exceeded the first four rules of arithmetic, and did not always extend so far, may be found all that is necessary for a first year's course for classes in connection with the Science and Art Department, and that it may aid the inexperienced teacher in his work.

The book may advantageously be used as follows : First, the student should be led carefully through the first 87 pages, the teacher patiently illustrating, and then making his class illustrate in turn, the different paragraphs on actual mineral specimens, and on carefully prepared models of crystals. In the hands of a good teacher, who should have some knowledge of practical chemistry, this part of the work will be found both easy and pleasant ; and if a few of the models be compared with the corresponding figures of crystals, even a dull student will soon learn to recognise these latter as representations of solids, and not of mere plane figures.

The teacher should next commence Part II., and illustrate on actual specimens, as far as possible, the properties of each mineral, such as hardness, specific gravity, behaviour before the blowpipe, and the like ; at the same time practising his pupils in drawing from memory some of the chief crystal forms. By such means the interest of the pupils will be kept up, especially if they be taken out for occasional excursions in search of mineral specimens, such as may be found in all mining districts. Their knowledge should also be tested from time to time by means of such questions as will be found at the end of the book, and by presenting minerals to them for their recognition. They should also be encouraged and aided to form illustrative collections of their own, as far as possible.

Without a collection of the minerals mentioned in the book, and a set of models, the teacher will only be able to *cram* his pupils ; with the aid of such appliances, he may give them practical knowledge capable of daily application, and a taste for the higher branches of a science of special educational value.

J. H. C.

POLYTECHNIC HALL, FALMOUTH,  
*January, 1873.*



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# MINERALOGY.

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## PART I.

### CHAPTER I.

#### INTRODUCTORY.

1. ANY natural substance which has never formed part of a plant or animal, and which is in all parts of the same chemical composition, is called a **Mineral**. These conditions are embodied in the short scientific definition, "Minerals are *natural, homogeneous, inorganic* bodies."

This definition includes *water*, and accordingly many treatises on mineralogy describe *ice*, the solid form of water, as a mineral. On the other hand, if strictly applied, it would exclude coal, amber, and some few other substances which are of *vegetable* origin, but which are nevertheless usually described in mineralogical works.

2. **Rocks** are *mineral substances*, but not *minerals*. Many of them are made up of several distinct minerals mingled together, such as *granite*, which is composed of at least three minerals, known as *quartz, felspar, and mica*. Many other rocks are simply masses of some one mineral in a more or less impure state; thus limestone is an impure massive form of the mineral *calcite*. The study of rock-masses belongs to **Geology**, of which science Mineralogy may be regarded as an important branch.

3. **Minerals** have many peculiar chemical properties, so that the complete knowledge of mineralogy necessarily includes some knowledge of the science of **Chemistry**.

Minerals have also many peculiar optical and other physical characters, the complete study of which belongs to the branch of science called **Physics**.

4. The study of minerals may be conveniently divided into six sections, as follows—dividing for convenience, the *optical* from the other *physical* characters :—

1. FORM.
2. PHYSICAL CHARACTERS.
3. OPTICAL CHARACTERS.
4. CHEMICAL CHARACTERS.
5. DISTRIBUTION.
6. PARAGENESIS.

We shall now proceed in succeeding chapters to describe the points which are of most importance to the elementary student in each of these sections.

---

## CHAPTER II.

### OF THE FORMS OF MINERALS.

5. **MINERALS** may be either *crystallized*, *crystalline*, *imitative*, or *amorphous*.

Those minerals which occur in definite geometrical forms, such as are represented in fig. 6, and many other figures, are said to be *crystallized*, and the specimens are termed *crystals*; the process by which either natural or artificial crystals are formed is called *crystallization*.

Most crystals have a peculiar internal structure termed *crystalline*, as will be described in future chapters.

Masses of small and imperfectly formed crystals are also said to be crystalline.

6. Minerals sometimes occur in certain peculiar shapes termed *imitative*. The chief imitative forms are the following :—

*a. Globular.*—This is often seen in *wavellite*, *prehnite*, and other minerals, which seem to be composed of spheres, or parts of spheres, as shown in fig. 1.

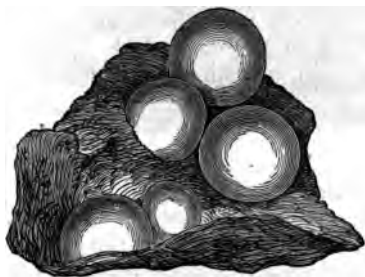


Fig. 1.

*b. Reniform (kidney-shaped).*—This is not unfrequently seen in nodules of *iron pyrites*, and other substances which occur imbedded in clay or mud (see fig. 2).



Fig. 2.

Some kinds of oxide of iron are called *kidney iron* from their occurrence in this form.

*c. Botryoidal (like a bunch of grapes).*—This form is



sometimes seen in *chalcopyrite* (yellow copper ore) of the kind called *blistered copper*. It is somewhat like the reniform pyrites (see fig. 3).

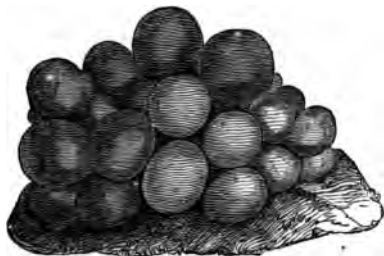


Fig. 3.

*d. Mammillary.*—This form consists of rounded prominences, which are not so distinctly separated from each other as in the form called globular. It is frequent in *malachite* and *yellow copper ore* (fig. 4).

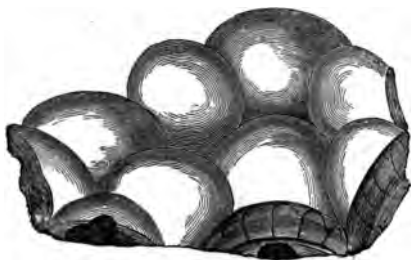


Fig. 4.

*e. Stalactitic (icicle-shaped).*—This form is frequently seen in the minerals *calcedony* and *calcite* (fig. 5).

7. Minerals which are not known to crystallize are said to be *amorphous*. Particular specimens of other minerals, which may happen to be without the crystalline form or structure, are also sometimes called amorphous. Both

crystalline and amorphous minerals occur sometimes in the imitative forms above described.



Fig. 5.

8. The numerous forms in which *crystals* occur are, for convenience of study, usually grouped into six "systems," and that branch of science which treats of these forms is called **Crystallography**.

In each system the flat surfaces of the crystals are called *planes*, and this term is retained even when they may be, as is sometimes the case, rough or curved. The line formed by the meeting of two planes is termed an *edge*, and the point formed by the meeting of three or more planes a *solid angle*. Thus in fig. 6, *a a a* and *b b b* are the planes, *c c c*, *f f f*, and *g g g* are edges, *d d d* and *e* are solid angles—*d d d* being four-sided and *e* a six-sided solid angle.

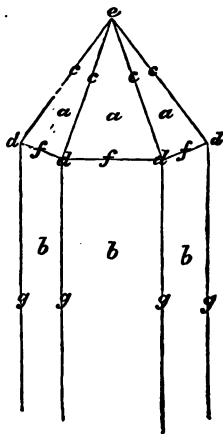


Fig. 6.

In all crystals the planes are referred to certain

imaginary lines running through the crystal termed *axes*. The point within the crystal at which the axes cross is called its *centre*, and that part of each axis extending from the centre to the surface of the crystal is called a *parameter*.

9. We have said that the planes of all crystals are "referred" to the axes. This is a very important point, and no student should proceed until he has mastered the meaning of the expression. We will endeavour to make it clear by the aid of diagrams.

In fig. 7, let the three black lines  $a a' b b' c c'$  represent three stout wires, each two inches long, crossing each

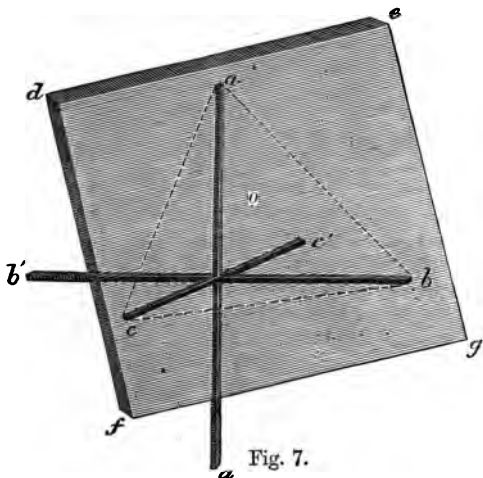


Fig. 7.

other at right angles. Now, if a small pane of glass  $o$ , triangular or otherwise, be placed so as to rest upon the three points  $a b c$ , the flat surface of the glass will have a certain definite *slope*. If we take three other wires longer or shorter than these, but still of *equal* length, a pane of glass made to rest upon their points will have exactly the same kind and degree of *slope*.

Now take three wires, as shown in fig. 8, crossing each other at right angles, just as in fig. 7, but the wire  $a a'$

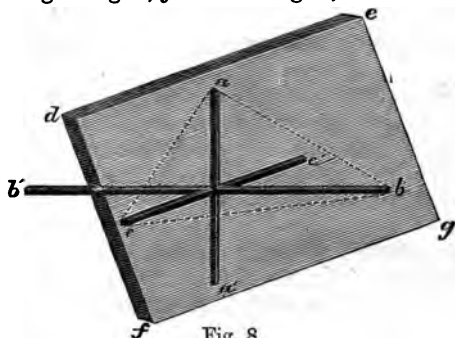


Fig. 8.

only half as long as the other two. A pane of glass resting upon the points of the wires will now, too, have a definite slope, but one quite different from that of fig. 7; of course the shape of the triangle will be different, but that at present is unimportant. Whatever the *actual* length of the wires, so long as the wire  $a a'$  is only half as long as the other two, this second kind of slope will be obtained.

In all such instances it is clear that if we once know the relative lengths of the wires, or, in other words, the relative distances from the centre at which they are met or "cut" by a plane, we shall know the degree of slope of the plane.

Now, taking the three wires to represent three axes of a crystal, and the pane of glass to represent one of its planes, these figures will show what is meant by "referring" a plane to certain axes. Whether the plane cuts the axes at equal distances or unequal, so long as those distances are indicated in some way, the nature of the plane is indicated also.

## CHAPTER III.

## OF SOME TERMS USED IN THE STUDY OF CRYSTALS.

10. THE faces or *planes* of crystals are of very various forms, and some of these forms are of very frequent occurrence. The chief of these are the *triangle*, the *square*, the *rectangle*, the *rhomb*, the *rhomboid*, the *deltoid*, the *trapezium*, the *pentagon*, the *hexagon*, and the *octagon*.

a. The **Triangle** is a figure bounded by three straight lines. Triangles may be *equilateral*, having three equal sides, as in fig. 9; *isosceles*, having two sides equal and

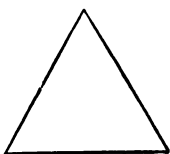


Fig. 9.

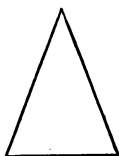


Fig. 10.



Fig. 11.

the other shorter (fig. 10), or longer (fig. 11); or *scalene*, having three unequal sides (fig. 12).

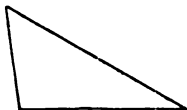


Fig. 12.

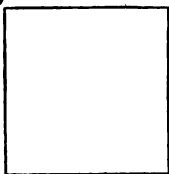


Fig. 13.

b. The **Square** is a four-sided figure, having the sides equal and the angles right angles (fig. 13).

c. The **Rectangle** is also a four-sided figure with the angles right angles, but the opposite sides only are equal (fig. 14).

d. The **Rhomb** is a four-sided figure with all the sides equal, but its angles are not right angles (fig. 15).

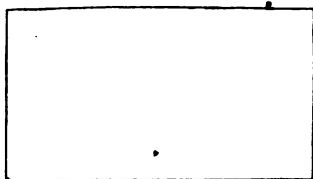


Fig. 14.

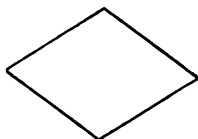


Fig. 15.

e. The **Rhomboid** has the same relation to the *rhomb* as the *rectangle* to the *square*, its opposite sides only being equal, the angles not right angles (fig. 16).

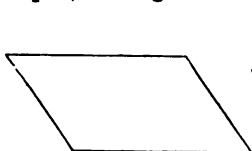


Fig. 16.

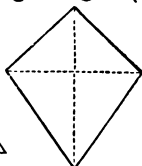


Fig. 17.



Fig. 18.

f. The **Deltoid** is a four-sided figure of such a form that one of its diameters will divide it into two *equal scalene* triangles, and the other into two *unequal isosceles* triangles (fig. 17).

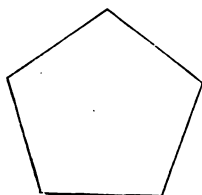


Fig. 19.

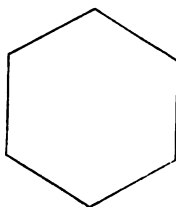


Fig. 20.

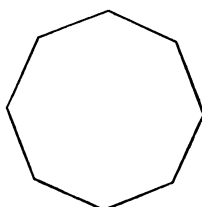


Fig. 21.

g. The **Trapezium** is a four-sided figure having none of its sides parallel (fig. 18).

*h.* The **Pentagon** is a five-sided figure—in the regular pentagon the sides are equal (fig. 19).

*i.* The **Hexagon** is a six-sided figure—in the regular hexagon the sides are equal (fig. 20).

*k.* The **Octagon** is an eight-sided figure—in the regular octagon the sides are equal (fig. 21).

11. Besides the *plane* figures above described, many *solid* figures have received special names. Of these we may specially describe the *prism*, *pyramid*, *octahedron*, *hexahedron* or *cube*, *rhombohedron*, *rhombic dodecahedron*, *deltahedron*, *tetrahedron*, *scalenoedron*, and *pentagonal dodecahedron*.

*a.* The **Prism** is a solid figure contained by planes, of which two are *equal*, *opposite*, *similar*, and *parallel*, the rest rectangles or rhomboids. Fig. 22 represents a prism with square base; fig. 23 with hexagonal base.



Fig. 22.



Fig. 23.



Fig. 24.

*b.* The **Pyramid** is a solid, the base of which is any plane figure, and its side triangles meeting in a point. A



Fig. 25.

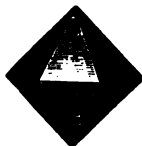


Fig. 26.

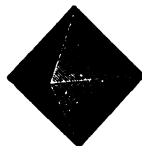


Fig. 27.

complete crystallographic pyramid is made up of two such figures placed base to base. Figs. 24 and 25 represent two such pyramids having *square* bases, but of different elevations; fig. 26 is a pyramid with an *hexagonal* base.

c. The **Octahedron** is a solid figure bounded by eight planes. Figs. 24 and 25 are octahedrons, but fig. 27 is the *regular* octahedron, bounded by eight equal equilateral triangles.

d. The **Cube**, or **Regular Hexahedron**, is bounded by six equal squares (fig. 28).

e. The **Rhombohedron** is bounded by six equal rhombs. It may be acute (fig. 29), or obtuse (fig. 30).



Fig. 28.



Fig. 29.

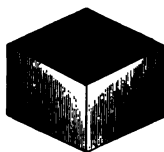


Fig. 30.

f. The **Rhombic Dodecahedron** is bounded by twelve equal rhombs (fig. 31).

g. The **Deltahedron** is bounded by twenty-four equal deltoids (fig. 32).

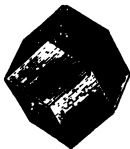


Fig. 31.

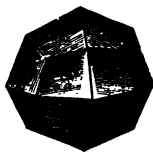


Fig. 32.



Fig. 33.

h. The **Tetrahedron** is bounded by four triangles. Fig. 33 is the *regular* tetrahedron.

i. The **Scalenoedron** is bounded by twelve equal scalene triangles. It may be acute (fig. 34), or obtuse (fig. 35).



k. The **Pentagonal Dodecahedron** is bounded by twelve equal pentagons (fig. 36).



Fig. 34.



Fig. 35.



Fig. 36.

## CHAPTER IV.

### OF THE SIX SYSTEMS OF CRYSTALLOGRAPHY.

12. We have explained how a crystal plane may be said to be referred to the crystal axes. In figs. 7, 8 only *one* plane is applied to the axes, to the points  $a\ b\ c$ . It is clear, however, that similar planes may be applied to  $a'\ b'\ c'$ ,  $a''\ b''\ c''$ , and all the other points around the centre, forming a complete crystal, all the planes having reference to the axes. If the axes were equal in length, and crossing each other at right angles, the figure produced would be the regular octahedron (fig. 27). Crystals so produced are called **holohedral**, or *whole-sided*.

13. If, instead of applying planes all round the centre to each set of three points, we apply them only to each alternate set of three, omitting the others, we shall produce a set of figures called **hemihedral**, or *half-sided*. In the *hemihedral* forms the *slopes* of the faces will be the same as those of the holohedral, but the complete forms are very different, as an inspection of fig. 37 will show. Here  $a\ a',\ b\ b',\ c\ c'$  are the three axes;  $a\ b\ c$  is a *holohedral* plane, and  $d\ d\ d$  is the corresponding and much larger *hemihedral* plane;  $d\ d\ d$  corresponds with the plane  $a'\ b'\ c'$ ;

$a' b' c$  and  $a' b c$ , it will be seen, have no corresponding hemihedral planes in the figure.

14. The axes have neither the same relative length, nor the same situation with regard to each other in all crystals, nor are they always the same in number. The six systems are based upon the number, situation, and relative lengths of the axes. They are as follows :—

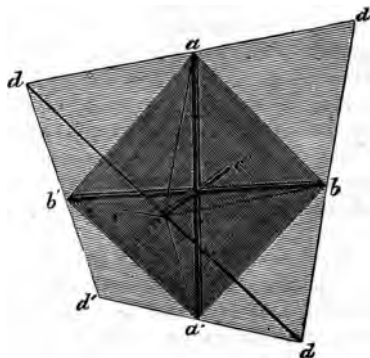


Fig. 37.

(1) **Cubical** (*Octahedral, &c.*).—In this system there are three axes at right angles to each other, and equal in length.

(2) **Pyramidal** (*Tetragonal, &c.*).—Three axes at right angles, but one longer or shorter than the others, which is called the *principal*; the other two are called *lateral*. In some pyramidal crystals the principal axis is *longer*, in others *shorter*, than the lateral.

(3) **Rhombic** (*Prismatic, &c.*).—Three axes at right angles, all unequal in length. One of these is selected for the *principal*, the others are called *lateral*. The longer of the lateral axes is termed the *macro-diagonal*, or greater diagonal, the shorter *brachy-diagonal*, or lesser diagonal.

(4) **Oblique** (*Monoclinic, &c.*).—Three axes, length

unimportant, two at right angles, the third with an inclination. One of the two which are at right angles is called *principal*, that at right angles is termed the *orthodiagonal*, or right diagonal; that which is inclined is called the *clino-diagonal*, or inclined diagonal.

(5) **Anorthic** (*Doubly Oblique, &c.*).—Three axes, length unimportant, all inclined. Either may be taken as principal, when the longer of the other two will be the *macro*, the other the *brachy-diagonal*.

(6) **Hexagonal** (*Rhombohedral, &c.*).—In this system there are four axes, three are *lateral*, *equal*, *lying in one plane*, and inclined to each other  $60^\circ$ ; the fourth is the *principal axis*, at right angles to the other three, and of any length.

15. In either of these systems there may be both *prisms*, *pyramids*, *holohedral* or *hemihedral* forms, as will be shown hereafter.

When crystals are very long and narrow in proportion to their thickness, they are often termed *acicular*, or “needle-shaped,” when broad in proportion to their thickness they are said to be *tabular*. Both acicular and tabular crystals occasionally occur in each of the crystallographic systems.

## CHAPTER V.

### OF THE HOLOHEDRAL FORMS OF THE CUBICAL SYSTEM.

16. In this system there are three axes, equal in length, and situated at right angles to each other. The chief forms are as follow:—

17. (1) The **Octahedron** (*Regular Octahedron*, fig. 38).—This, when complete, is bounded by eight equal equilateral triangles. Its planes form with each other angles of  $109^\circ 28'$ . The axes join the opposite solid

angles. As its planes meet the axes at equal distances from the centre, in other words, as its *parameters* are equal, its symbol may be written 1.1.1. Sometimes the symbol O.O.O. is adopted, O being the initial letter of octahedron, and this is contracted by Naumann to O. These symbols may be regarded as the symbols of any particular face; or, as each face has the same relations to the axes, of the whole crystal. It is a common form of *cuprite* and *magnetite*.

18. (2) The **Cube** (*Hexahedron*, fig. 39).—This is bounded by six equal squares. Its planes form with each other angles of  $90^\circ$ . The axes join the centres of opposite faces. A little consideration will show that each face "cuts" one of the axes at a certain distance from the centre, while it is parallel to the other two; that is, it does not cut them at all, or, as some would express it, "cuts" them at an *infinite* distance. The symbol of the crystal will therefore be 1.O.O., or in Naumann's mode  $\infty O \infty$ . Here the sign  $\infty$ , meaning infinity, implies that a plane is parallel to a given axis, or meets it at an infinite distance. As each plane is parallel to two of the axes, this sign is repeated twice. The cube is a very common form of *pyrites* and *fluor*.

19. (3) The **Rhombic Dodecahedron** (fig. 40) is bounded by twelve equal rhombs, its faces form with each other angles of  $120^\circ$ . The axes join the opposite



Fig. 38.

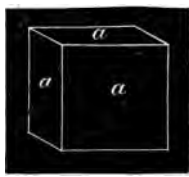


Fig. 39.



Fig. 40.

*four-sided* solid angles. As each plane cuts two axes at equal distances, and is parallel to a third, the

symbols will be 1.1.0, or  $\infty 00$ , usually contracted to  $\infty 0$ . It is a frequent form of *garnet* and *galena*.

20. (4) The Three-faced Octahedron (*Triakis Octahedron*, fig. 41) is bounded by twenty-four equal isosceles triangles. The axes join the opposite *eight-sided* solid angles. The angles, measured over the edges from face to face, are often different in different crystals. Each plane cuts two axes at equal distances from the centre, but the third is cut at a distance always greater than the other two, but sometimes only a little exceeding them in length, at others greatly exceeding them. This variable quantity, more than one and less than infinity, is indicated by the letter *m*, so that the symbol of each face, or of the complete form, will be 1.1.*m* or *mOO*, which latter is contracted to *mO*. This form occurs sometimes in the *diamond* and in *pyrites*. It is evidently like an octahedron, in which three planes have been built over each of the original, hence the name. The thicker line around one group of faces shows the edges of the octahedral plane.



Fig. 41.



Fig. 42.



Fig. 43.

21. (5) The Deltahedron (fig. 42) is bounded by twenty-four equal deltoids. The axes join the opposite *four-sided* solid angles. The angles from face to face are often different in different crystals. Each plane cuts one axis at the normal distance, called 1, and the other two at distances greater than 1, but less than infinity, and equal to each other, the symbol will therefore be 1.*m.m* or *mOm*. This form occurs frequently in *garnet* and *leucite*.

22. (6) The **Six-faced Octahedron** (fig. 43) is bounded by twenty-four equal triangles, which are usually scalene. The axes join the opposite eight-sided solid angles. The angles, from face to face, are often different in different crystals. Each plane cuts one axis at the normal distance, a second at a distance greater than one and less than infinity, called  $m$ , and a third at a distance greater than  $m$  and less than infinity, called  $n$ . The symbols will therefore be  $1.m.n$  or  $mOn$ . This form occurs in the *diamond* and *cuprite*. The thicker line round one group of faces is intended to show the relation of the groups to each other.

23. (7) The **Four-faced Cube** (fig. 44) is bounded by twenty-four equal isosceles triangles. The axes join the opposite four-sided solid angles. The angles, from face to face, are often different in different crystals. Each plane cuts one axis at the normal distance, is parallel to a second, and cuts the third at a distance ( $m$ ) greater than one and less than infinity. The symbols will therefore be  $1.m.O$  or  $\infty Om$ . This form occurs frequently in *fluor* and *cuprite*.

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## CHAPTER VI.

### OF THE HEMIHEDRAL FORMS OF THE CUBICAL SYSTEM.

24. THE meaning of the term hemihedral has been sufficiently explained in Chap. IV., Sec. 13. We now proceed to describe the hemihedral forms of the seven figures already explained.

25. (1) The **Tetrahedron** (fig. 45) is the hemihedral form of the octahedron (fig. 38). It is bounded by four equal equilateral triangles; its faces correspond with four alternate faces of the octahedron: the angle from face to face is  $70^{\circ} 32'$ . The axes join the central points of the edges. As its faces have the same slope as those of the octahedron their sign will be the same, but to indicate their hemihedral

nature, it is written with the sign of division, thus :  $\frac{m}{2}$  or  $\frac{\infty}{2}$  contracted to  $\frac{o}{2}$ . It is a common form of *blende* and *fahlerz*.

26. (2) The **Trigonal Dodecahedron** (fig. 46) is bounded by twelve equal isosceles triangles. Its angles are variable. The axes join the central points of the longer edges. It is



Fig. 44.

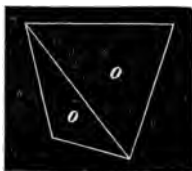


Fig. 45.

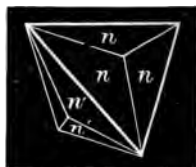


Fig. 46.

the hemihedral form of the *deltohedron*, its planes corresponding with alternate groups of three planes of that figure. Its symbol will therefore be  $\frac{1mn}{2}$  or  $\frac{mOn}{2}$ . It is a common form of *fahlerz*.

27. (3) The **Deltoid Dodecahedron** (fig. 47) is bounded by twelve equal deltoids. Its angles are variable. Its axes join the opposite four-sided solid angles. It is the hemihedral form of the *three-faced octahedron*, its planes corresponding with alternate planes of that figure. Its symbol will therefore be  $\frac{11m}{2}$  or  $\frac{mOo}{2}$  or  $\frac{mO}{2}$ . It is a common form in *fahlerz*.

28. (4) The **Six-faced Tetrahedron** (fig. 48) is bounded by twenty-four equal scalene triangles. Its angles are variable. Its axes join the opposite four-sided solid angles. It is the hemihedral form of the *six-faced octahedron* (fig. 43), its planes corresponding with alternate groups of six planes of that figure. Its symbol will therefore be  $\frac{1mn}{4}$  or  $\frac{mOn}{4}$ .

29. (5) The **Trapezohedron** (fig. 49) is bounded by twenty-four equal trapeziums. The axes join the opposite *equiangular* four-sided solid angles. Like the *six-faced tetrahedron* (fig. 48), it is the hemihedral form of the *six-faced octahedron* (fig. 43), but it is derived according to a

different law. In the former the planes correspond with alternate *groups* of planes, in the latter with alternate

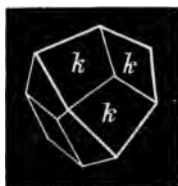


Fig. 47.



Fig. 48.



Fig. 49.

planes. The slope of each plane, however, corresponds with that of one of the planes of the six-faced octahedron, so that its symbol is also  $\frac{1m}{2}$  or  $\frac{m0}{2}$ . To distinguish it from fig. 48, however, it is enclosed in brackets, thus  $[\frac{m0}{2}]$ . It is a common form of *pyrites* and *cobaltite*.

30. (6) The **Pentagonal Dodecahedron** (fig. 50) is bounded by twelve equal pentagons. The axes join the central points of the opposite longer edges. Its angles are variable. It is the hemihedral form of the *four-faced cube* (fig. 44). Its planes correspond in slope with the alternate planes of that figure, so that its symbol will be  $\frac{1m0}{3}$  or  $\frac{m0m}{3}$ . It is a common form of *pyrites* and *cobaltite*.

31. In the first four of these hemihedral figures, no face is parallel to any other. In Nos. (5) and (6), however, each plane has another parallel to it. They are therefore sometimes called the *parallel-faced* hemihedral forms.

## CHAPTER VII.

### OF THE SIMPLER COMBINATIONS OF FORMS IN THE CUBICAL SYSTEM.

32. Of the thirteen distinct forms of crystals in the previous two chapters, several are often combined together in one crystal, so as to produce what are called *combinations*.



33. Fig. 51 shows such a combination of the *octahedron* and *cube*—the planes marked *o* being those of the octahedron, those marked *a* the cube. It will be seen that the *slopes or inclinations* of the octahedral planes are not in the least interfered with; they have the same situation with reference to the axes and the same angle of inclination,  $109^{\circ} 28'$ , to each other. The planes are now, however, no longer triangles, as in the original octahedron, but irregular *hexagons*. From this we learn, that, except in the simple forms, the *shape* of a plane is quite unim-

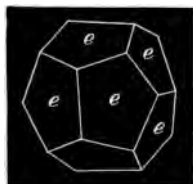


Fig. 50.

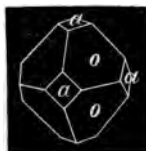


Fig. 51.

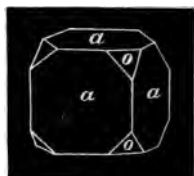


Fig. 52.

portant, while its slope or inclination is its essential character. The signs used to describe combinations are those of the planes placed one after the other, that of the *larger faces* first. The sign of fig. 51 will therefore be, according to Naumann's method,  $O : \infty O \infty$ . It is a form which commonly occurs in *cuprite*.

Fig. 52 is also a combination of the cube and octahedron, but here the cubical faces are the largest; the letters *a o* are used as in fig. 51. Symbol  $\infty O \infty : O$ . A common form of *galena* and *cuprite*.

34. Fig. 53 shows a combination of the *octahedron* (*o*) and *rhombic dodecahedron* (*d*). As the octahedral planes are the largest, the sign will be  $O : \infty O$ . It is found not unfrequently in *cuprite*.

Fig. 54 is also a combination of the octahedron and rhombic dodecahedron, the latter faces being the largest. Sign  $\infty O : O$ . Found in *cuprite*.

35. Fig. 55 is the *cube* (*a*) and *rhombic dodecahedron* (*d*).

Its symbol is  $\infty O \infty : \infty O$ . It occurs frequently in *fluor*.

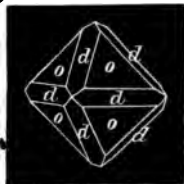


Fig. 53.



Fig. 54.

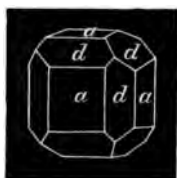


Fig. 55.

Fig. 56 is *rhombic dodecahedron* and *cube*,  $\infty O : \infty O \infty$ . It also occurs in *fluor*.

36. Fig. 57 is *cube*, *octahedron*, and *rhombic dodecahedron*. Symbol  $\infty O \infty : O : \infty O$ . It occurs in *galena*.

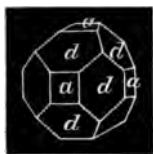


Fig. 56.

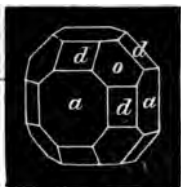


Fig. 57.



Fig. 58.

37. Fig. 58 is the *deltahedron* and *cube*. Symbol  $m O m : \infty O \infty$ .

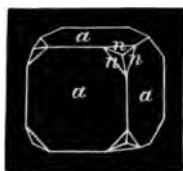


Fig. 59.

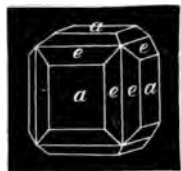


Fig. 60.



Fig. 61.

Fig. 59 is the same with the cubical faces much enlarged. Its symbol will be reversed. It is a common form of *analcite*.

38. Fig. 60 is the *cube* and *four-faced cube*. Symbol  $\infty O \infty : \infty O m$ . It is a very common form of *fluor*.

39. Fig. 61 is the *rhombic dodecahedron* (*d*) and *deltohedron* (*n*). Symbol  $\infty O : m O m$ . It is not uncommon in *garnet*.

40. Fig. 62 is the *tetrahedron* (*o*) combined with the opposite *tetrahedron* (*o'*). Its complete sign is  $+\frac{o}{2} : -\frac{o}{2}$ , the larger planes being regarded as the *positive* tetrahedron. By enlarging the planes *o'* until they become as large as the planes *o*, the octahedron will evidently be produced. This is expressed by saying that  $\pm \frac{o}{2} = O$ .

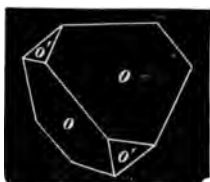


Fig. 62.

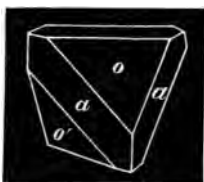


Fig. 63.

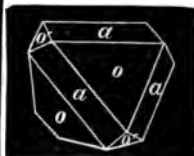


Fig. 64.

41. Fig. 63 is the *tetrahedron* (*o*) and *cube* (*a*). Symbol  $\frac{o}{2} : \infty O \infty$ .

42. Fig. 64 is the *tetrahedron* (*o*) *cube* (*a*) and *negative tetrahedron* (*o'*). Symbol  $\frac{o}{2} : \infty O \infty : -\frac{o}{2}$ .

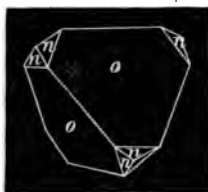


Fig. 65.

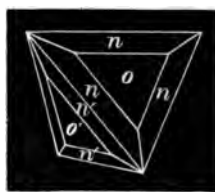


Fig. 66.

43. Fig. 65 is the *tetrahedron* (*o*) and *deltohedron* (*n*). Its sign is  $\frac{o}{2} : \frac{\infty O n}{2}$ .

Fig. 66 is the *tetrahedron* (*o*) and *four-faced cube* (*n*). Its sign is  $\frac{o}{2} : \frac{\infty O n}{2}$ .

44. Fig. 67 is the *tetrahedron* (*o*), *four-faced cube* (*n*), and *rhombic dodecahedron* (*d*). Its sign is  $\frac{o}{2} : \frac{\infty O n}{2} : \infty O$ .

Figs. 65, 66, 67, are common forms of *fahlerz*.

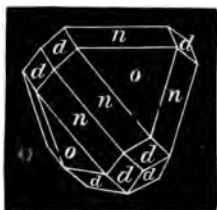


Fig. 67.

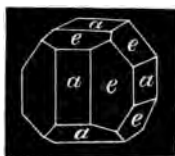


Fig. 68.

45. Fig. 68 is the *pentagonal dodecahedron* (*e*) and *cube* (*a*). Its symbol is  $\frac{\infty m}{3} : \infty O \infty$ . It is a common form of *pyrites* and *cobaltite*.

Fig. 69 is the *pentagonal dodecahedron* and *deltahedron*. Its symbol is  $\frac{\infty m}{3} : m O m$ . It is a common form of *pyrites* and *cobaltite*.

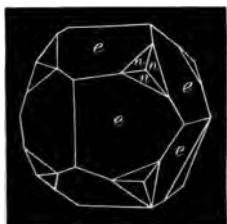


Fig. 69.



Fig. 70.

46. Fig. 70 is a puzzling form which is occasionally met with. It is a combination of the *octahedron* (*o*) with the *deltahedron* (*n*); with the sign  $O : m O m$ . The triangles *o* are equilateral, but the others are usually isosceles.

Very many other combinations occur occasionally in crystals, but these are the most important and common. It will be seen that in all cases the slope or inclination of the planes remains unaltered, but that the shape of the planes is constantly being interfered with by other planes.

## CHAPTER VIII.

## OF THE PYRAMIDAL SYSTEM.

47. In this system there are three axes, as in the cubical, and they are also placed at right angles to each other; but they are not equal in length, one being shorter or longer than the other two. This is called the *principal axis*, while the two that are equal in length are called lateral.

In trying to discover the nature of a crystal in the cubical system, to "read" it, as crystallographers say, one axis should be placed upright or vertical; but it is quite unimportant which one. In the pyramidal and all the other systems, however, the *principal axis* must invariably be vertical.

48. The **Holohedral** forms of the pyramidal system are either *pyramids*, *prisms*, or combinations of these.

49. The **Tetragonal Pyramid** (figs. 71, 72) is bounded



Fig. 71.



Fig. 72.

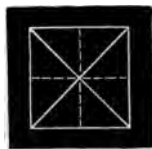


Fig. 73.

by eight isosceles triangles. They are therefore *octahedrons*, but not *regular* octahedrons. Tetragonal pyramids occur in *cassiterite*. The edges *t t t t*, running to the principal axis, are called *polar edges*; those marked *s s* are the *lateral edges*.

Tetragonal pyramids are of two orders, exactly alike in appearance, and differing only in the position of the lateral axes. In pyramids of the first order, the lateral axes join the lateral solid angles; in those of the second order,

the centres of the lateral edges. Fig. 73 is a top view of a tetragonal pyramid, the completed lines showing the positions of the lateral axes of a pyramid of the first order, the dotted lines those of the second order.

The general symbol for the pyramids of the first order is  $mP$  or  $nP$ ; for those of the second order,  $mP\infty$ , and these symbols are usually contracted to  $P$  and  $P\infty$ .

50. The **Tetragonal Prism** (fig. 74) is bounded by two equal squares, and four equal rectangles. There are two orders of prisms, differing only in the positions of their axes. In both, the principal axis joins the central points of the top and bottom planes, called the *basal* planes. In the prisms of the first order, the lateral axes join the central points of the vertical edges; in those of the second order, the central points of the lateral planes. The symbol of the basal planes is always  $OP$ , so that the complete symbol of the prism of first order will be  $\infty P + OP$ ; that of the second order,  $\infty P\infty : OP$ . These prisms occur in *cassiterite* and *idocrase*.



Fig. 74.

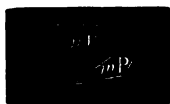


Fig. 75.



Fig. 76.

51. The **Tetragonal Sphenoid** (figs. 75, 76) is the hemihedral form of the tetragonal prism. It is a *tetrahedron*, but not a regular tetrahedron; but sometimes it very closely resembles the regular tetrahedron. It is bounded by four equal isosceles triangles. The axes join the central points of the opposite edges. Symbol  $\frac{P}{2}$ . It is a common form of *chalcopyrite*.

52. The **Ditetragonal Pyramid** (fig. 77) is a combination of the tetragonal pyramids of the first and second

orders. It is bounded by sixteen equal isosceles triangles. The principal axis joins the *eight-sided* angles, and the

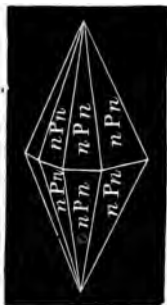


Fig. 77.



Fig. 78.

lateral axes the centres of the alternate lateral edges. Its symbol is  $mP + mP\infty$  or  $P + P\infty$ . It occurs in *cassiterite* and *anatase*. There are other ditetragonal pyramids of the second order bounded by *scalene* triangles. In these the lateral axes join the alternate lateral solid angles, as shown in fig. 78. The symbol of these pyramids will be  $nPn$ .

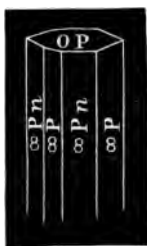


Fig. 79.



Fig. 80.

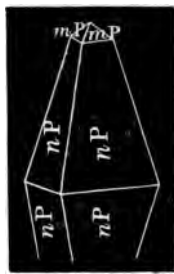


Fig. 81.

**53. The Ditetragonal Prism** (fig. 79) is bounded by two regular octagons and eight equal rectangles. It is a combination of the prisms of the first and second orders.

The principal axis joins the centres of the octagonal basal planes, while the lateral axes join the centres of alternate vertical faces. Its symbol is  $\infty P : \infty P \infty : O P$ . There are other ditetragonal prisms in which the basal planes are irregular octagons. In these the lateral axes join the alternate solid angles, as in fig. 78. These forms occur in *cassiterite* and *rutile*.

54. The **Tetragonal Scalenohedron** (fig. 80) is bounded by eight equal scalene triangles. It is the hemihedral form of the ditetragonal pyramid. The principal axis joins the two equal tetragonal solid angles. The lateral axes join the central points of alternate opposite edges. Its symbol is  $\frac{mP}{2} = \frac{mP}{2}$  when derived from the first order of ditetragonal pyramid, and  $\frac{mP}{2}$  when derived from the second order.

55. Very often several pyramids of different degrees of acuteness or steepness occur in the same crystal. Fig. 81 shows a combination of a steep or acute pyramid  $n P$ , and a less steep or obtuse pyramid  $m P$ , which occurs sometimes in *cassiterite*.

Fig. 82 shows the pyramid of the first order  $m P$ , that of the second order  $m P n$ , and the prism  $\infty P$ . This is common in *cassiterite*.

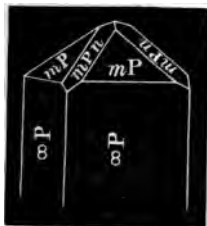


Fig. 82.

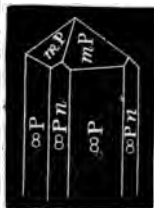


Fig. 83.

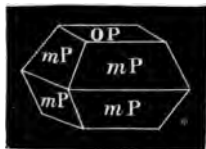


Fig. 84.

Fig. 83 is the prism of first order  $\infty P$ , pyramid of first order  $m P$ , and prism of second order  $\infty P n$ . This is also common in *cassiterite*.

Fig. 84 shows the pyramid of first order  $m P$ , and the basal plane  $o P$ . A common form in *anatase*.



## CHAPTER IX.

## OF THE RHOMBIC SYSTEM.

56. In this system there are three axes situated at right angles to each other, but all unequal in length. Either one of these may be taken for the principal, and placed vertically. The longer of the other two is called *macro-diagonal*, the shorter *brachy-diagonal*.

The chief forms are pyramids and prisms, as in the pyramidal system. They may be briefly described as follows:—



Fig. 85.



Fig. 86.



Fig. 87.

57. The **Right Rhombic Pyramid** (figs. 85, 86).—This is bounded by eight equal *scalene* triangles; but when these scalene triangles are nearly *isosceles*, the pyramids are much like the tetragonal pyramids (figs. 71, 72). The axes join opposite solid angles. Symbol  $mP$  or  $nP$ , usually contracted to  $P$ . It occurs commonly in *barytes*.

58. The **Right Rhombic Prism** (fig. 87) is bounded by four equal rectangles and two equal rhombs. Its principal axis joins the central points of the rhombs, the lateral axes join the central points of the vertical edges. When the macro-diagonal and brachy-diagonal axes are nearly equal, the prisms are much like the tetragonal prisms (fig. 74). Its symbols are in the fig., it occurs in *topaz*. Fig. 88 shows the position of the lateral axes in the right rhombic prism and pyramid.

59. The **Right Rectangular Pyramid** is bounded by

eight *isosceles* triangles in two sets—four larger, four smaller. The principal axis joins the vertical solid angles; the *macro-diagonal* axis joins the central points of the *shorter* lateral edges, while the *brachy-diagonal* joins similar points in the longer lateral axes. The symbol is  $\bar{\infty}P\infty : \bar{\infty}P\infty$ , the signs — and ~ indicating respectively the macro-diagonal and brachy-diagonal axes, to which the corresponding planes are parallel. It occurs in *bournonite*.

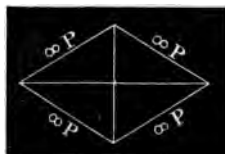


Fig. 88.

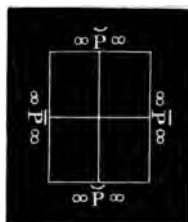


Fig. 89.

**60. The Right Rectangular Prism** is bounded by six rectangles equal to each other in opposite pairs. The axes join the central points of opposite planes. It occurs in *bournonite* and *topaz*. Symbol  $\infty\bar{P}\infty : \infty\hat{P}\infty : OP$ . Fig. 89 shows the position of the lateral axes.



Fig. 90.

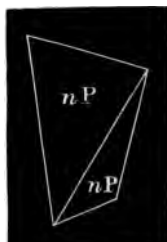


Fig. 91.

**61. The chief hemihedral forms** are the rhombic sphenoids (figs. 90, 91). They are much like the tetragonal sphenoids, but bounded by *scalene* triangles instead of *isosceles*.

The principal axis joins the central points of the top and bottom edges; the lateral axes join the central points of



Fig. 92.

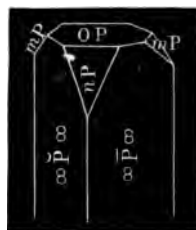


Fig. 93.

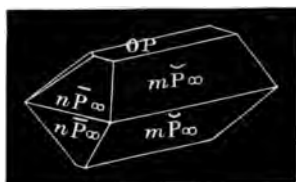


Fig. 94.

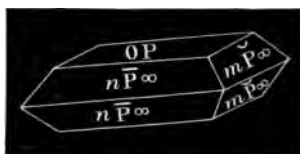


Fig. 95.

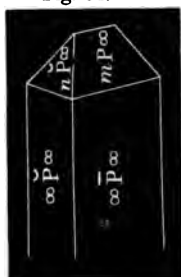


Fig. 96.



Fig. 97.

the other four edges, when the symbol is  $\frac{m}{2}$  or  $\frac{P}{2}$ , or the central points of the faces when it is  $\frac{m}{4}$  or  $\frac{P}{4}$ .

62. Figs. 92 to 99 represent different combinations of



Fig. 98.

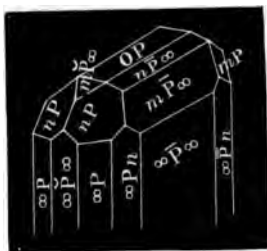


Fig. 99.

forms in the rhombic system, the corresponding planes of which have similar lettering.

## CHAPTER X.

### OF THE OBLIQUE AND ANORTHIC SYSTEMS.

63. In the oblique system there are three axes, the relative lengths of which are quite unimportant; these are called *principal*, *ortho-diagonal*, and *clino-diagonal*.

The principal axis is placed vertically, the ortho-diagonal is at right angles to it, and the clino-diagonal at right angles to the ortho-diagonal, but inclined to the principal. When the clino-diagonal is nearly at right angles to the principal, the forms are so very similar to those of the rhombic and pyramidal systems that the same figures of the primary forms will serve. The symbols, too, are scarcely different. The differences in form are far better seen in models than in drawings. We shall, therefore, only briefly describe the simple forms, and give figures of some of the more common combinations, especially as the simple forms are very rare in natural crystals.

64. The Oblique Rhombic Pyramid is bounded by

eight scalene triangles—four larger and four smaller—in pairs. The axes join the four-sided solid angles. Planes of this form occur in *orthoclase* and *gypsum*. Its symbol is  $mP$  or  $P$ .

65. The **Oblique Rhombic Prism** is bounded by four equal rhomboids and two equal rhombs. The principal axis joins the centres of the rhombs, the lateral axes the centres of the vertical edges. Planes of this form occur in *epidote* and *vivianite*. Symbol  $\infty P : OP$ .

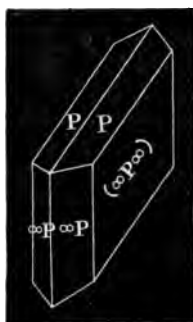


Fig. 100.

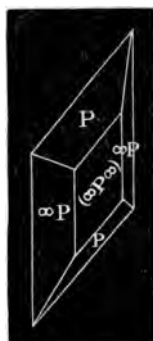


Fig. 101.

66. The **Oblique Rectangular Pyramid** is bounded by four isosceles triangles—two larger and two smaller—and four equal scalene triangles. The principal axis joins the vertical solid angles, the ortho-diagonal the centres of the edges, formed by pairs of scalene triangles; and the clino-diagonal the centres of the edges formed by each two isosceles triangles. It occurs in *orthoclase* and *vivianite*. Symbol  $P\infty : (P\infty)$ , the bracketed symbol indicating the planes which are parallel to the *clino-diagonal*.

67. The **Oblique Rectangular Prism** is bounded by four rectangles and two rhomboids, the opposite planes being equal. The axes join the centres of opposite planes. It occurs in *orthoclase* and *gypsum*. Its symbol is  $\infty P\infty : (\infty P\infty) : OP$ .

The foregoing forms are *holohedral*—hemihedral forms are rare; the chief is,

68. The **Oblique Sphenoid**, bounded by four scalene triangles—two larger and two smaller. The axes join the central points of the edges. Its symbol is  $\frac{\infty P}{2}$  or  $\frac{P}{2}$ .

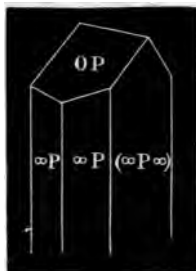


Fig. 102.

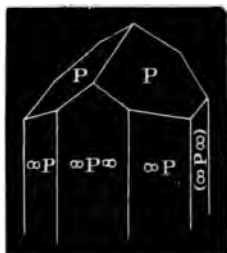


Fig. 103.

Figs. 100 to 104 represent combinations of forms in the oblique system, the planes having their appropriate symbols placed upon them.

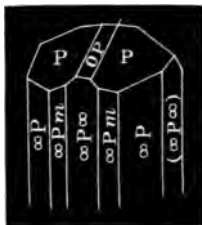


Fig. 104.

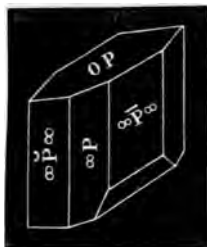


Fig. 105.

69. In the **Anorthic** system there are three axes, all inclined and of unimportant length. When the inclinations are small, the simple forms will be much like those of the pyramidal, rhombic, and oblique systems. By some writers, indeed, the rhombic, oblique, and anorthic systems are regarded as one. In the anorthic system, crystals are rare, and simple forms are *extremely* rare, and often

very unsymmetrical. We, therefore, give only three

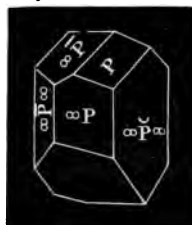


Fig. 106.

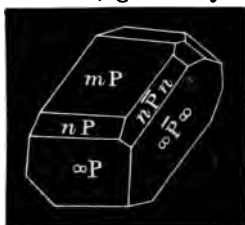


Fig. 107.

figures, 105 to 107, showing the more common and simple combinations.

## CHAPTER XI.

### OF THE HEXAGONAL SYSTEM.

70. In this beautiful system, unlike all the others, there are four axes, three *lateral*, of equal length, lying in one plane, and inclined to each other  $60^\circ$ ; the fourth, the principal, which is of variable length, and placed at right angles to the other three. The chief *holohedral* forms are the following:—

71. The **Hexagonal Pyramid** (figs. 108, 109), bounded by twelve equal isosceles triangles. The principal axis joins the two six-sided solid angles; the lateral axes join the lateral solid angles, forming pyramids of the *first* order, or the central points of the lateral edges, forming pyramids of the *second* order. Fig. 110 shows the positions of the lateral axes in these two orders of pyramids, as well as in the corresponding prisms—the dark lines representing the first order, the dotted lines the second order. This is the only difference in the two orders of pyramids, there being no difference in their appearance. Hexagonal pyramids occur frequently in *quartz* and *corundum*. The general symbol for the first order will

P, usually contracted to P; and for the second  $mP2$ , or  $nP2$ , usually contracted to P2.



g. 108.



g. 110.

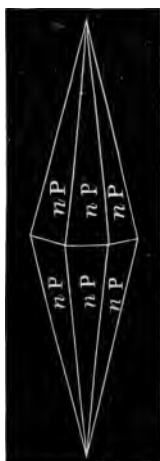


Fig. 103.

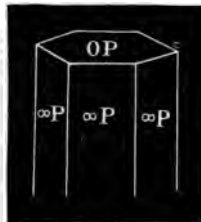


Fig. 111.



Fig. 112.

The **Hexagonal Prism** (fig. 111) is bounded by rectangles and two regular hexagons. The chief planes join the central points of the hexagons; the lateral planes join the central points of the vertical edges (first order), or of the vertical planes (second order). These occur in *apatite* and *calcite*. Symbol  $\infty P : OP$ .

The **Dihexagonal Pyramid** (fig. 112) is bounded by twenty-four equal isosceles or scalene triangles. When the triangles are isosceles it is a compound of the first and second orders of pyramids, and the lateral axes join the centres of alternate vertical planes; when they are scalene, it is a totally different figure, and the lateral axes join the centres of alternate vertical edges. The dihexagonal pyramids occur in *apatite*. The symbol of the first kind will be  $mP : mP2$ ; of the second kind,  $mPn$ .

The **Dihexagonal Prism** (fig. 113) is bounded



by twelve rectangles and two regular or irregular dodecahedral planes. When these planes are *regular*, the axes correspond in position with those of the first kind of dihexagonal pyramid; when the dodecahedral planes are irregular, with the second kind. It occurs in *calcite* and *apatite*. Symbols of the first kind  $\infty P : \infty P_2 : OP$ , of the second kind  $\infty P_n : OP$ .

75. The chief *hemihedral* forms are *rhombohedrons* and *scalenohedrons*.

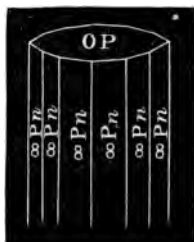


Fig. 113.



Fig. 114.

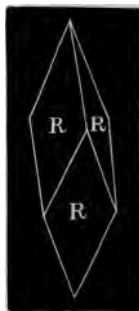


Fig. 115.

The **Rhombohedron** (figs. 114, 115) is bounded by six equal rhombs. It is the hemihedral form of the hexagonal pyramid. When the original pyramid is short, as in fig. 108, the rhombohedrons will be obtuse, like fig. 114; when long, the derived rhombohedron will be acute, like fig. 115. The principal axis joins the two equal three-sided solid angles, the lateral axes join the other solid angles when derived from the pyramid of the *first* order, or the centres of the edges when from the *second* order. Rhombohedrons are common in *calcite* and *dolomite*. The symbols are  $\frac{\infty P}{2}$  or  $\frac{\infty P_2}{2}$ , but usually they are indicated by the special symbol R.

76. The **Scalenohedron** (fig. 116) is bounded by twelve equal scalene triangles. The principal axis joins the two six-sided solid angles, the lateral axes join alternate lateral solid angles. It is a hemihedral form of the

dihexagonal pyramid; but it is more usually derived from the rhombohedron, as shown in fig. 117. It occurs in *calcite* and *chalybite*. Symbol  $R_n$ , the  $n$  indicating the amount by which the axis of the rhombohedron has been lengthened.

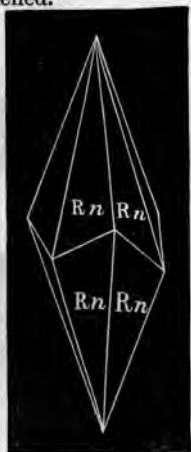


Fig. 116.

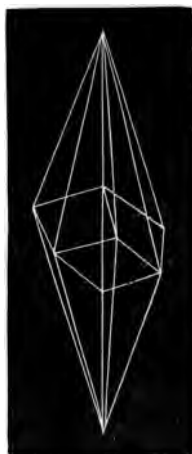


Fig. 117.

77. We give below some of the chief combinations in this system, the planes having their appropriate signs:—

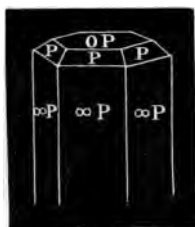


Fig. 118.



Fig. 119.

Figs. 118, 119 are combinations of prisms and pyramid.

Fig. 120 is a combination of pyramid of first order, with prism of second.

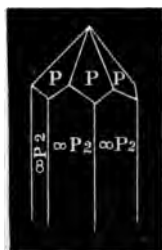


Fig. 120.

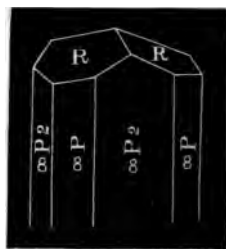


Fig. 121.

Fig. 121 is a combination of prisms of first and second order, with a rhombohedron.

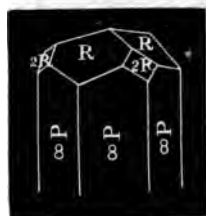


Fig. 122.

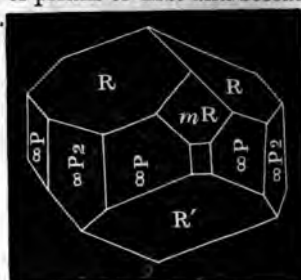


Fig. 123.

Figs. 122, 123 are combinations of two rhombohedrons

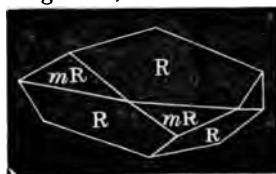


Fig. 124.



Fig. 125.

of different steepness, with the prism of first and second order,

Fig. 124 shows two rhombohedrons of different steepness— $R$  and  $mR$ .

Fig. 125 is the same, with the addition of the basal plane.

Fig. 126 shows an acute rhombohedron and the basal plane.

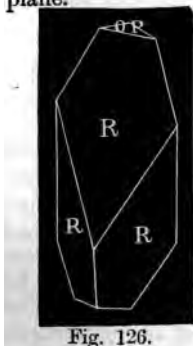


Fig. 126.



Fig. 127.

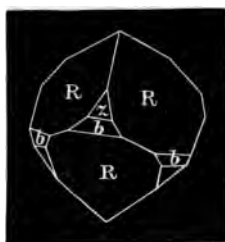


Fig. 128.

Fig. 127 shows the union of rhombohedron with prism of second order.

Fig. 128 shows the union of the rhombohedron with the prism  $\infty P_2$  ( $b$ ) and an acute rhombohedron ( $z$ ).

Fig. 129 shows a combination of the prism  $\infty P$  ( $a$ ) the rhombohedron  $R$ , another rhombohedron ( $e$ ), and the basal plane  $OP$ .

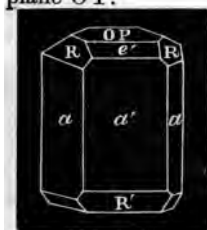


Fig. 129.

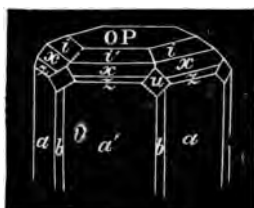


Fig. 130.

Fig. 130 shows the prism of first order  $\infty P$  ( $a$ ) of



second order  $\propto P2$  ( $b$ ), three pyramids of first order ( $i, x, z$ ), a pyramid of second order ( $u$ ), and the basal plane  $OP$ .

## CHAPTER XII.

### OF MACLES AND IRREGULAR CRYSTALS, AND OF THE MEASURING OF THE ANGLES OF CRYSTALS.

**78. Macles, twin crystals or hemitropes**, are groups of two or more crystals which appear as if mutually intersecting each other, or sometimes as if a single crystal had been cut in two in a certain direction, one part turned round a certain number of degrees and then re-united. The axis around which the portions move, or may be supposed to move, is the *twin axis*, and the plane of movement is the *twin plane*. Thus, if the octahedron (fig. 131) be cut in two, in the direction of the dotted lines or twin plane, the one-half rotated on the axis  $90^\circ$ , and then the two pieces be re-united, a macle like fig. 132 will be the result—a form which occurs frequently in *spinel*, *alum*, and other minerals. Of course no such division and re-union has really taken place, the whole crystal has probably taken that peculiar form from its first origin. The twin axes of macles are always inclined to each other, and to the principal axes of their parts, in accordance with very precise laws.

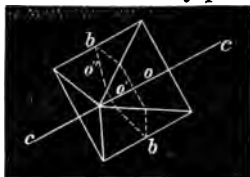


Fig. 131.

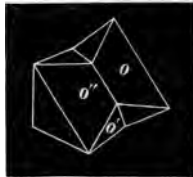


Fig. 132.

**79.** Figs. 132 to 151 represent macles of different kinds

in which the corresponding planes are marked with corresponding letters.

Fig. 132 is a maced octahedron which occurs in *spinel* and *magnetite*.

Fig. 133 represents maced octahedrons occurring occasionally in *fluor*.

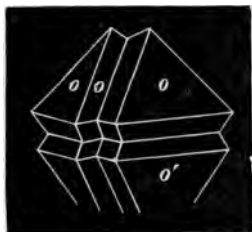


Fig. 133.

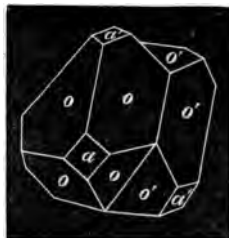


Fig. 134.

Fig. 134 shows maced octahedron and cube occurring in *cuprite*.

Fig. 135 shows maced cubes, common in *pyrites*.

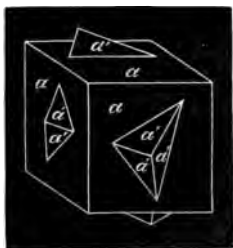


Fig. 135.

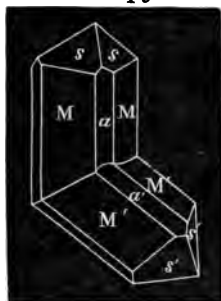


Fig. 136.

Figs. 136, 137 represent maced pyramids with prisms of *cassiterite* and *rutile*.

Fig. 138 represents a macle which occasionally occurs in *chalcocite*.

Figs. 139, 140 show forms which occur frequently in *staurolite*.

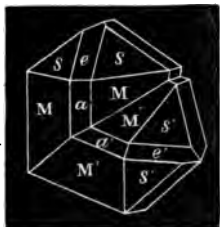


Fig. 137.

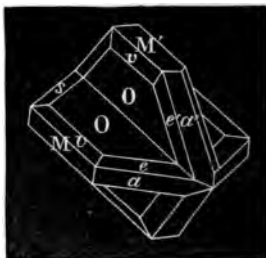


Fig. 138.

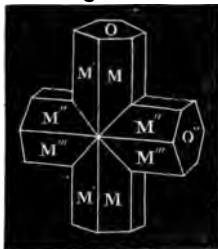


Fig. 139.



Fig. 140.

Fig. 141 is a complex macle of *bournonite*.

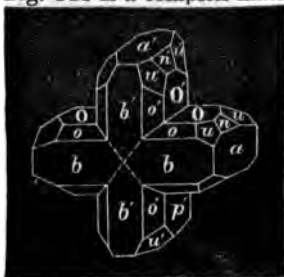


Fig. 141.

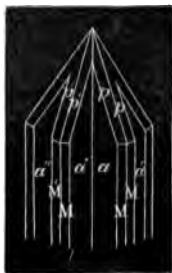


Fig. 142.

Fig. 142 is a macle of *cerussite*.

Fig. 143 is a frequently occurring macle of *marcasite*.



Fig. 144 is a macle of *wolfram*.

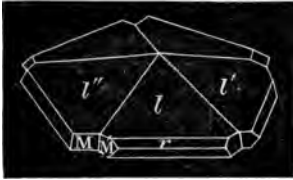


Fig. 143.

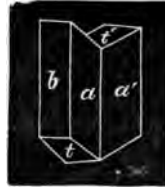


Fig. 144.

Fig. 145 is a common maced form of *pyroxene* (augite)

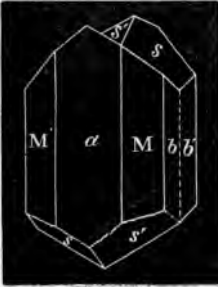


Fig. 145.



Fig. 146.

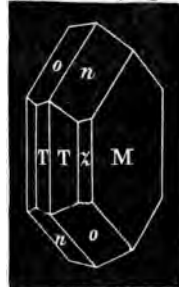


Fig. 147.

Fig. 146 is the most common macle of *orthoclase*.

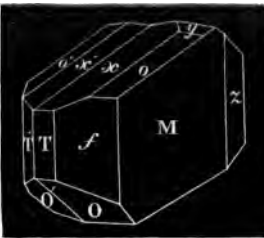


Fig. 148.



Fig. 149.

Fig. 147 is also a macle of *orthoclase*.

Fig. 148 is a frequently occurring macle of *albite*.  
Figs. 149, 150 are sometimes observed in *quartz*.

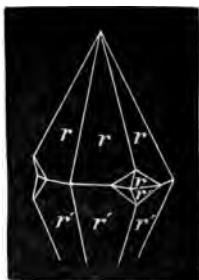
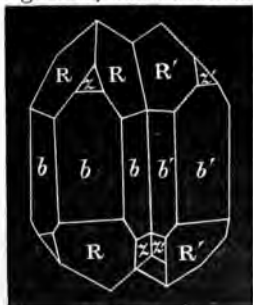


Fig. 151 is a very frequent maced form of calcite.

Maced crystals may generally, but not always, be recognised by their re-entering angles.

80. Both simple and maced crystals have occasionally some or all their planes curved, striated, or roughened. *Diamond* and *dolomite* are often curved; *pyrites*, *cassiterite*, and *topaz*, striated; and *axinite* roughened. Simple crystals, too, are often bent or otherwise distorted, or lengthened in one direction, or prisms are lengthened and tapering, so as to be quite unlike the perfect form. Sometimes, too, from a deficiency on one plane, the whole crystal will be much altered in appearance.

81. When the same substance crystallizes in two distinct forms, having different axes, it is said to be *dimorphous*. Thus *calcite* and *aragonite* are dimorphous forms of carbonate of lime. When different substances crystallize in the same form, they are said to be *isomorphous*; thus the carbonates of lime, magnesia, iron, zinc, and manganese, are isomorphous, since they all crystallize in the hexagonal system, in forms which are very nearly similar.

82. **Pseudomorphous** crystals are those which have the form of one mineral and the composition of another. They are usually the products of the slow change of

mineral substances in the earth. Thus, at Huel Coates, in St. Agnes, Cornwall, many fine crystals of orthoclase are found, some of which are partly, others entirely, changed into *cassiterite* or oxide of tin, while the form of the original crystal is perfectly retained.

83. In most cases of irregularity in simple crystals, and combinations of forms, the angles which similar planes make with each other are constant, however much the general aspect of the crystal may vary. To measure these angles, instruments called *goniometers* are used. These are of two kinds, called the *contact* and the *reflecting* goniometer.

84. The common or contact goniometer consists of a small semi-circle divided into degrees, and a pair of moveable brass arms jointed in the centre. In using this instrument, the moveable arms are applied to the crystal, as shown in fig. 152, until the two arms are accurately resting upon the planes, in a direction *at right angles* to the included *edge*. The screw *s* is then tightened and the arms are applied to the brass semi-circle, as shown in fig. 153, when the number of degrees of inclination may be read off.

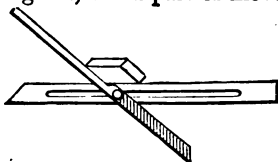


Fig. 152.

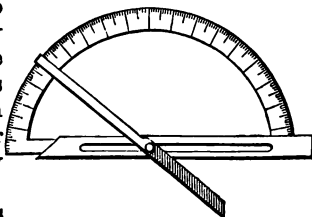


Fig. 153.

This mode of measuring is sufficient for the beginner, but it is difficult to get *very* accurate results, and it is not applicable to very small crystals.

85. For the more advanced student the reflecting goniometer is used. In this instrument the crystal is attached to a revolving graduated circle, so that the reflection of a window bar or other object from one of its surfaces is made to fall upon a given spot. The crystal is then turned round

by means of a milled screw, until the same object is reflected to the same place by the next face. The amount of movement is read off from the graduated circle; and in good hands the instrument is so accurate that very small crystals may be measured within less than a second of arc.

86. Crystals are sometimes sprinkled with minute crystals of the same or another mineral—they are then said to be *drusy*. Sometimes they are covered over with a thin layer of another mineral, when they are said to be *invested*. Sometimes a crystal appears to be made up of a great number of smaller crystals, thus an octahedron of fluor is sometimes apparently made up of an immense number of small cubes. Such crystals are called *complex*, *compound*, or *polysynthetic*.

87. Distinct crystals and crystalline grains of different minerals are sometimes intermixed irregularly together so as to form rock masses. These rocks are called *granular* or *granitic*. Granite is such a rock, composed of a mixture of crystalline particles of quartz, felspar, and mica.

Sometimes distinct crystals are imbedded in a non-crystalline mass, forming what are called *porphyries* or *porphyritic* rocks. The Elvan rocks of Cornwall are mostly porphyritic.

In other cases the crystalline grains occur in distinct layers or thin bands, forming *foliated* rocks. Gneiss is a foliated rock composed of quartz, felspar, and mica, while mica-schist consists of quartz and mica.

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## CHAPTER XIII.

### OF THE SO-CALLED PHYSICAL CHARACTERS OF MINERALS.

88. THE crystalline form of such minerals as occur in distinct crystals is a character of much importance, but perfect

crystals are generally rare, and many common minerals do not crystallize at all. The study of the other physical characters of minerals becomes, therefore, of the highest importance to all beginners, and, fortunately, this study is much more easy than that of crystalline form. The chief physical characters of minerals—excluding form and optical characters—may be arranged under the following heads :—

CLEAVAGE.	TOUCH.
STRUCTURE( <i>except cleavage</i> ).	SPECIFIC GRAVITY.
FRACTURE.	MAGNETISM.
FRANGIBILITY or TENACITY.	ELECTRICITY.
HARDNESS.	

**89. Cleavage.**—This is the property possessed by many *crystallized* and *crystalline* minerals of splitting in certain directions more readily than in others, and affording shining surfaces, sometimes *curved*, but usually *plane*, and called *cleavage planes*. The cleavages are usually parallel to the faces of one of the simpler forms of the mineral. These cleavages are spoken of as *perfect*, when very smooth and readily obtained, and less perfect, or *imperfect*, when obtained with difficulty and not so smooth. Thus, *calcite* has a very perfect, and *quartz* an imperfect cleavage. Sometimes cleavages are spoken of as *highly perfect*, *very perfect*, *perfect*, *imperfect*, and *very imperfect*. Cleavage planes often render great assistance to the crystallographer in “reading” crystals, being always in the same direction in the same mineral; thus,

Diamond, fluor, magnetite, and some other minerals, cleave parallel to the faces of the *octahedron*.

Galena, rock salt, and other minerals, have perfect cleavages parallel to the faces of the *cube*.

Blende has a perfect cleavage parallel to the faces of the rhombic *dodecahedron*.

The cleavage of a mineral is always mentioned as a part of its complete description when known.

The cleavage of rocks is, in some respects, similar to that of minerals, but it is a distinct phenomenon.

**90. Structure.**—Properly speaking, the cleavage of crystals is part of the structure of minerals, but it is more convenient to treat it separately. The chief varieties of structure, as distinct from cleavage, are called,

*a. Fibrous.*—Made up of thin, straight, or curved fibres lying side by side. They have often a silky lustre. *Satin spar* is a name given to fibrous varieties of *gypsum* and *aragonite*, in which this silky lustre is very strongly marked.

*b. Reticulate.*—The same as fibrous, but the fibres crossing each other irregularly in all directions, as in the mineral called *mountain leather*.

*c. Stellate.*—The fibres radiating from centres in all directions, as in *stilbite* and some varieties of *gypsum*.

*d. Radiate or Divergent.*—The fibres diverging from each other, but not producing complete stars, as in *antimonite* and *pyrolusite*.

*e. Tabular.*—The mineral breaks more or less readily into thick plates, as in *barytes*.

*f. Lamellar.*—The mineral appearing to consist of flattened leaves or laminæ, as in *bronzite*.

*g. Foliateous or Micaceous.*—The leaves being very thin, as in *mica* and *selenite*.

*h. Granular.*—Apparently made up of minute grains, as in *chalk* or *kaolin*.

**91. Fracture.**—Any broken surface other than a *cleavage plane*, or *plane* of union, of two or more crystals.

According to its general form it may be—

*a. Conchoidal* (shell-like).—Having curved markings like those seen on the inside of many bivalve shells, as in *flint* and *opal*.

*b. Even.*—A surface free from marked depressions or elevations, as in *chalcocite*.

*c. Uneven.*—A surface having irregular depressions or elevations, as in *cassiterite*.

According to the nature of the broken surface the fracture may be—

- d. *Smooth*, as in *lithomarge*.
- e. *Splintery*, as in *serpentine*.
- f. *Earthy*, as in *kaolin*.
- g. *Hackly*, or covered with sharp wire-like points, as in *native copper*.

**92. Frangibility or Tenacity.**—Minerals may be—

- a. *Tough*, or only broken with difficulty, as *hornblende*.
- b. *Brittle*.—Parts of the mineral fly off in powder on attempting to cut or scratch it. Very easily broken with a blow, as *tourmaline* (schorl).

c. *Sectile*.—Thin pieces may be cut off with a knife, but the mineral falls to powder by hammering, as *chalcocite*.

d. *Malleable*.—When slices may be cut off and flattened under the hammer, as native copper.

e. *Friable* or *Pulverulent*.—The mineral is easily crushed between the fingers to a powder.

f. *Elastic*.—The mineral may be bent, but springs back to its former position when the bending force is removed. Example, *mica*.

g. *Flexible*.—The mineral may be bent, and remain so after the bending force is removed. Example, *talc*.

**93. Hardness.**—This is a character of much importance in the discrimination of minerals. It is usually expressed by comparison with the following "Scale of hardness :"—

- |                           |                |
|---------------------------|----------------|
| 1. TALC.                  | 6. ORTHOCLASE. |
| 2. GYPSUM (or Rock Salt). | 7. QUARTZ.     |
| 3. CALCITE.               | 8. TOPAZ.      |
| 4. FLUOR.                 | 9. CORUNDUM.   |
| 5. APATITE.               | 10. DIAMOND.   |

The hardness of a mineral may be determined in different ways :—

1. By attempting to scratch it with the minerals in the above list successively.

2. By passing a finely cut file over the specimens, with a rather firm pressure, three or four times.

3. By attempting to scratch the specimen with a knife.

Several trials should be made to obtain certain results, and each method should be tried if possible. Thus, suppose the specimen is a piece of *chalcocite*, No. 2 (*gypsum*) fails to scratch it, but No. 3 (*calcite*) scratches its surface readily. Next, reverse the method, it is found that the specimen under trial will scratch No. 2 readily, but not No. 3. On trying it with the file it is not rubbed away so readily as No. 2, but more readily than No. 3. It would be sufficient to set down its hardness at 2.5.

94. Easy as this method may seem, some precautions are, nevertheless, necessary. Thus, in a fibrous specimen, a scratch directed *across* the fibres will always indicate a lower degree of hardness than the true one, the scratch should therefore be parallel to the fibres, or still better, on the surface of a transverse fracture.

A sound, undecomposed specimen should always be selected, since the hardness of minerals is greatly affected by decomposition. Many minerals are *softer* when first obtained, than after they have been kept some time in a dry cabinet. In crystals, the edges and angles are often considerably harder than the faces, and those of the primitive form than of the modifications. The portion of the specimen selected for trial should be, as nearly as possible, of the same shape as that of the comparative specimens.

95. Brittleness should not be mistaken for hardness. Many minerals which are too hard to be scratched, are yet forced away in powder before the knife to some extent.

Some minerals contain hard particles of foreign matter imbedded in them—these should not be overlooked.

96. A series of substitutes has been arranged for use when a scale of hardness is not available; *i.e.*—

1. May be readily impressed with the finger nail.
2. Is scarcely impressed with the nail; does not scratch a plate of copper.
3. Scratches a piece of copper, but is also scratched by it.



4. Is not scratched by a piece of copper, but does not scratch glass.

5. Scratches glass slightly; is easily scratched with a knife.

6. Scratches glass easily; is scratched a little with a good knife.

7. Is not scratched with a knife, but yields to a file.

8. Cannot be filed, but scratches a rock crystal.

9. Scratches a topaz.

10. Scratches a ruby.

**97. Touch.**—A property of some importance in the discrimination of minerals. Thus, some minerals feel *unctuous*, like *graphite* and *talc*; others feel *harsh*, like *actinolite*; others, again, feel *meagre*, like *magnesite*.

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## CHAPTER XIV.

### OF THE PHYSICAL CHARACTERS OF MINERALS—(*Continued*).

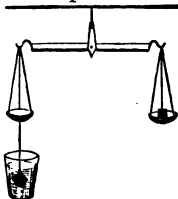
**98. Specific Gravity.**—This term is used to express the weight of a substance as compared with some other substance. It is a character of much practical importance in mineralogy. Water is always the standard of comparison for minerals; thus, the specific gravity of water is said to be 1, that of silver 10.5, meaning that silver is  $10\frac{1}{2}$  times heavier than an equal bulk of water.

The specimen to be examined should be free from foreign matter and from decay, unless it is the specific gravity of such a specimen which is actually wanted. It should also be free from cavities; when these are suspected, the specimen should be powdered.

**99.** The following methods will suffice for all minerals, the first for such as are in compact masses, the second and third for similar masses, for small fragments, or for liquids.

1st Method.—*a.* Weigh the specimen carefully in an ordinary pair of scales.

*b.* Suspend it by a horsehair from below the scale pan, let it dip well under the surface of water in some convenient



vessel, as shown in fig. 154, and again weigh it. It will be found that fewer weights will balance it than in the first weighing.

*c.* Subtract the weight in *b* from that in *a*, the difference will be the weight of a bulk of water exactly equal to the specimen.

*d.* Divide the weight *a* by the difference *c*, the quotient will be the specific gravity.

Example—*a.* Weight in air, . 43.1 grains.

*b.* Weight in water, 27.2

*c.* Difference, . . 15.9

*d.*  $43.1 \div 15.9 = 2.71$ , the specific gravity of the specimen.

2nd. Method.—Procure a small *specific gravity bottle*, a light glass bottle with a mark on the neck, or better, a perforated stopper, so arranged as to hold a known weight of water—say 500 grains. Fill it with water, insert the stopper, and wipe it dry. Now, make a counterpoise of exactly the weight of the filled bottle.

*a.* Weigh off any convenient quantity of the specimen less than the capacity of the bottle, viz., 500 grains, and in fragments not too large to go into the bottle.

*b.* Put the weighed fragments into the bottle, taking care to lose none. Of course, as the bottle was already filled with water, some will now run out. It is also evident that the water which runs out must be of exactly the same bulk as the mineral introduced. Having again inserted the stopper and wiped the bottle, it will be found that the counterpoise, together with a smaller number of weights than those used to balance the fragments in *a*, will produce equilibrium.

c. The difference will be the weight of the displaced water, i.e., of a bulk of water equal to the specimen.

d. Divide the weight of mineral in *a* by the difference *c*, the result will be the specific gravity required.

Example.—301 grains of fine sand were carefully weighed out. The sand was placed in the bottle, when it was found that, besides the counterpoise, 185 grains were required to produce equilibrium. The difference, then, of course represented the weight of water displaced by the sand.

a. Weight of sand in air = 301

b. Weight in water = 185

c. Difference = 116

d.  $301 \div 116 = 2.59$  the specific gravity of the sand.

3rd Method.—Specific gravities are often determined by means of Nicholson's areometer, a little instrument which is made in many forms, one of the most convenient of which is represented in fig. 155. This is a hollow, pear-shaped body (*a*), usually of brass, having a wire stem, which supports a little cup (*b*), and another suspended cup below (*c*). The whole apparatus is so arranged as just to sink in a tall jar of water to a mark (*d*) placed on the wire stem, when a given weight, called the *balance weight*, is placed in the cup *b*. The specimen to be experimented upon must not exceed this weight, which we will suppose to be 100 grains, the quantity marked upon the body of the instrument.

The fragment is placed in the cup *b*, weights are added until the instrument sinks to the mark *d* on the stem. The difference between the weight used and 100 grains, of course, equals the weight in air (*a*) of the specimen.

It is now taken from the cup *b* and placed in the cup *c*, when, as the mineral is buoyed up by



Fig. 155.

the water, the instrument will rise, and more weights must be added until it again sinks to the mark *d*. This latter quantity is the weight of the water displaced by the mineral (*c*). Now, divide the original weight of the specimen (*a*) by this difference (*c*), the quotient will be the specific gravity required.

Example.—The specimen was placed in cup *b*, 24·57 grains were added to bring the aræometer down to the mark, then  $100 - 22·57$  or 77·43 grains equal the weight of the specimen. It was now placed in cup *c*, when it was necessary to add 35·43 grains to bring the instrument again down to the mark. This latter quantity is the weight of a bulk of water equal to the specimen. Now, divide 77·43 by 35·43, and the quotient is found to be 2·18, which is the specific gravity required.

**100. Magnetism.**—This property is not much used by beginners in finding out the nature of unknown minerals, but it is of great importance in practical mineralogy and geology, since the instruments used in surveying are often affected by magnetic substances. The mineral which has most magnetism is that called *magnetite*, or native loadstone. It sometimes occurs in large masses, and it very frequently occurs in minute grains disseminated through rocks, so as to render them magnetic throughout. This is the only mineral which will attract ordinary iron, but many minerals are attracted more or less by a magnet, or will attract a magnetized needle, such as is used for surveying instruments. The ores of manganese, nickel, and cobalt, have often this property in a small degree, as well as many ores of iron. Some mineral substances which are not naturally magnetic, become so after being heated, especially the carbonate of iron, which may be thus distinguished from several minerals which it much resembles, with great ease and certainty.

Magnetite has sometimes distinct magnetic polarity, that is, a particular point will *attract* one end of a freely suspended magnetic needle, while it *repels* the other end.

**101. Electricity.**—Many minerals become electrified, and capable of attracting light bodies after being heated or rubbed. These are said to be *pyro-electric* or *frictio-*

*electric*. Friction with a feather is sufficient to excite this electricity in some varieties of *blende*, while most *tourmalines* are pyro-electric. Some minerals, such as *topaz*, will retain their electricity for hours, others lose it in a few minutes.

102. A very simple and delicate electroscope for testing this property may be made from a bent glass rod, from which a minute fragment of gilt paper or gold leaf is suspended by a single fibre of silk. On approaching a substance whose electricity has been excited by any method, the suspended fragment will move towards it.

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## CHAPTER XV.

### OPTICAL CHARACTERS OF MINERALS.

103. THE chief optical properties of minerals are *colour*, *streak*, *lustre*, *diaphaneity* or *transparency*, *phosphorescence*, *refractive power*, *polarizing power*.

104. **Colour.**—The colours of minerals often afford useful aids to their recognition, especially in the case of those having metallic lustre. In most cases, however, of minerals having *non-metallic* lustre, the colour is liable to be much altered by the presence of minute proportions of accidental impurities, or from other causes, so that it is a character of little importance. Many *varieties* of the same mineral species are, however, named solely from their colour.

Some minerals appear to be of two distinct colours when viewed in different directions—this property is called *dichroism*; others appear of three or more tints—this is called *pleochroism*.

105. **Streak.**—The colour of the powder of a mineral. When the lustre is *metallic* the streak is dark, often darker than the colour of the mineral; when *non-metallic*, it is usually lighter than the colour.

Hematite may be readily distinguished from limonite, which it often much resembles, by its streak being *red* instead of *brown*. Wolfram, too, can be at once distinguished from blende by its darker streak. This test admits of being tried in cases where the specific gravity cannot be easily determined, as in *imbedded* crystals. It may also be usually tried without injury to the specimen.

The colour of the streak of a mineral is best determined by rubbing the specimen on a slightly roughened plate of white porcelain, when, if not too hard, some of it will be rubbed off. Very often a scratch with a knife suffices, or rubbing with a file, but the mark thus made in the specimen, the *scratch*, must then be distinguished from the colour of the abraded particles—the *streak*.

**106. Lustre.**—Most minerals shine with a peculiar *lustre*, which differs in different minerals. The chief varieties of lustre are:—

- a. *Metallic*, as seen in *pyrites* and *graphite*.
- b. *Adamantine* (diamond-like), as seen in the *diamond* and some varieties of *quartz*.
- c. *Resinous*, as seen in some kinds of *blende* and *cassiterite*.
- d. *Vitreous* (glassy), as in *fluor* and *calcite*.
- e. *Pearly*, as in *pearl-spar*, and *stilbite*. This is often seen on the cleavage planes of minerals not otherwise pearly.
- f. *Waxy*—seen in some varieties of *talc*.
- g. *Silky*—seen in “satin spar” (both kinds), and in most minerals having fibrous structures.

Each of the above varieties of lustre may vary in degree; thus, we may have—

- h. *Splendant*, as seen in *specular iron* and *galena*.
- i. *Brilliant*, as seen in *galena*.
- j. *Shining*, as seen in *dolomite*.
- k. *Glimmering*, as seen in *serpentine*.

A few minerals have no lustre—these are said to be *dull*. Many varieties of minerals have a lustre not perfectly metallic—these are said to be *sub-metallic*. The

true metallic lustre is only to be seen in minerals which are almost or entirely opaque, but not in all such.

**107. Diaphaneity or Transparency.**—A general term expressing the degree of transparency or opacity of mineral substances. The several degrees are :—

*a. Transparent.*—Outlines of objects may be seen distinctly through thick layers.

*b. semi-transparent.*—Outlines may be seen, but indistinctly.

*c. Translucent.*—Light passes through, but no outline can be seen.

*d. Sub-translucent.*—Light is only transmitted through thin edges or splinters.

*e. Opaque.*—No light is transmitted.

**108. Phosphorescence.**—Many minerals, after being heated, exposed to light, rubbed, or electrified, seem to glow or shine in a peculiar manner if taken into a dark place. This property is called phosphorescence. Thus, if a piece of fluor spar, especially the massive variety called chlorophane, be placed on a fire shovel and heated over the fire, or in a glass tube and heated over a spirit lamp, it will, when taken into a dark place, be seen to shine with a bright green light. If two lumps of quartz be rubbed together in a dark room, the surfaces will be seen to shine. If an electric shock be passed through a piece of chlorophane, a similar phosphorescence will be produced. It has long been observed of diamonds, that if taken into a dark room after exposure to the light of the sun, they will shine brightly.

Minerals which become phosphorescent from heat are sometimes called *pyro-phosphoric*, from friction *friction-phosphoric*, from electricity *electro-phosphoric*, from exposure to the light of the sun *helio-phosphoric*.

Sometimes a pyro-phosphoric substance, by repeated heating, loses its property of phosphorescence. This may be occasionally restored by passing a few electric shocks through the substance.

## CHAPTER XVI.

OF THE REFRACTIVE POWERS OF MINERALS AND THE  
POLARIZATION OF LIGHT.

**109. Refraction.**—When a ray of light falls upon a transparent substance in a direction at *right angles* to its surface, it passes through the substance without change of direction. When a similar ray, however, falls *obliquely* upon the surface, its direction is always changed in passing through. Thus, let  $aa$ ,  $bb$ ,  $dd$ , represent three rays of light passing from the lamp  $h$  (fig. 156) on to the

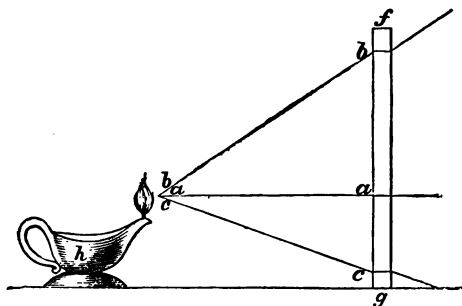


Fig. 156.

plate of glass  $fg$ , the ray  $aa$ , falling upon its surface perpendicularly, will pass through without change of direction; while the ray  $bb$ , which falls obliquely, will be bent out of its course towards the perpendicular at  $b$  while passing through the glass, but will pass on in a line parallel to its original direction after leaving the glass. The ray  $dd$  will be similarly bent towards the perpendicular in passing through the glass. This bending is called *refraction*, and it is possessed by all transparent bodies—although some substances bend or refract the ray of light more than others,



**110. Double Refraction.**—This is a property possessed by some transparent mineral substances, of not only bending or refracting rays of light falling obliquely, but of splitting each ray into two, and refracting one sometimes *more* sometimes *less* than the other, but always in accordance with a different and very complicated law; the latter portion is then called the *extraordinary* ray, while that which is bent in the ordinary manner is called the *ordinary* ray. Of all substances possessing the property of double refraction, that called Iceland spar, or double refracting spar—a very clear and transparent variety of calcite—shows it best. It is owing to this property of Iceland spar that all objects seen through that substance appear double, except when seen in one particular direction. This is called the axis of no double refraction. In the hexagonal and the tetragonal systems the axis of no double refraction is that of the principal axis, or optic axis, as it is sometimes called, of the crystal.

All transparent crystals, except those belonging to the cubical system, possess this property of double refraction; but only a few have it so powerfully as to cause an object seen through them to appear double. A very few cubical minerals have also been found to possess these peculiar refractive powers.

**111. Polarization.**—The light which passes through a doubly refracting crystal is changed in a peculiar manner. Thus, if one portion of a ray of light which has already passed through a rhomb of Iceland spar be made to pass through a second rhomb, it will not be again doubly refracted, and under certain circumstances it cannot be reflected from a shining surface. Light which has thus been changed is said to be polarized. The study of the peculiarities of polarized light falls more properly to the *advanced* than to the *elementary* student of mineralogy.

## CHAPTER XVII.

## OF THE CHEMICAL CHARACTERS OF MINERALS.

**112.** THE chief of the so-called chemical characters of minerals, or those which depend upon chemical composition, are—

TASTE.	FUSIBILITY.
ODOUR.	VOLATILITY.
SOLUBILITY.	

**113.** Taste is a character of great importance in the case of a few minerals.

Thus, *cyanosite* or blue vitriol, *goslarite* or white vitriol, *melanterite* or green vitriol, *halite* or common salt, *kalinite* or alum, *nitre*, *nitratite* or nitrate of soda, and a few other mineral substances, may be at once known by their taste, which is in each case very characteristic.

The chief varieties of taste observed in mineral substances are the following :—

- a. Astringent*—the taste of the vitriols.
- b. Sweetish astringent*—the taste of alum.
- c. Saline*—the taste of common salt.
- d. Alkaline*—the taste of nitrate of soda.
- e. Cooling*—the taste of nitre.
- f. Bitter*—the taste of Epsom salts.
- g. Sour*—the taste of sulphuric acid.

The only minerals which have distinct taste are those which are soluble in water.

**114.** Odour is occasionally of importance. Thus, many minerals containing alumina or magnesia give off a peculiar earthy smell when breathed upon ; others, which contain sulphur or arsenic, when broken, rubbed, or heated yield a characteristic smell.

The chief varieties of odour are the following :—

- a. Alliaceous*—the odour of garlic. It is obtained by rubbing, heating, or breaking ores containing *arsenic*.

*b. Horse-radish odours*—the odour of decaying horse-radish. It is obtained by heating or melting substances containing *selenium*.

*c. Sulphureous*—the odour of burning sulphur. Obtained in a similar manner from many substances containing *sulphur*.

*d. Fetid*—the odour of rotten eggs. It is given off by some varieties of quartz, barytes, and limestone when broken or rubbed.

*e. Argillaceous*—clayey. It is given off by serpentine, kaolin, and other substances containing alumina or magnesia.

**115. Solubility.**—This is shown on treating a powdered mineral with *water*, *acids*, or *alkalies*. The chief solvents used, and the order in which they are applied, are usually as follows :—

*a. Water.*

*b. Hydrochloric acid*—Dilute at first ; stronger afterwards if necessary.

*c. Nitric acid*—Dilute at first, then strong.

*d. Aqua Regia*—A mixture of hydrochloric and nitric acids.

*e. Special solvents*, such as sulphuric acid, ammonia, etc.

To ascertain the solubility of a mineral, a few grains of its powder should be placed in a test-tube or watch glass, and warmed with a few drops of the solvent. If the substance be *freely* soluble the powder will rapidly disappear ; but in other cases, to ascertain whether any portion is dissolved, a drop of the clear liquid should be evaporated to dryness on a slip of clean glass or of platinum foil, when, if there be any residue, it will be evidence of a certain amount of solution, as all the solvents above mentioned are volatilized completely by heat.

Any *effervescence*, *peculiar odour*, *change of colour or appearance*, should be carefully noted. Thus, sulphides may often be recognised by the unpleasant odour of sulphuretted hydrogen, which is given off when they are treated with hydrochloric acid, while carbonates are

readily recognised by the violent effervescence which takes place under similar treatment.

**116. Fusibility.**—This is a character of very great importance indeed. That some minerals will melt much more readily than others is speedily discovered by all who study minerals; but it is found convenient to have a comparative scale of reference. The scale of fusibility most usually adopted is the following :—

1. ANTIMONITE.
2. NATROLITE.
3. ALMANDINE—a variety of garnet.
4. ACTINOLITE.
5. ORTHOCLASE.
6. BRONZITE.

Of these, antimonite is so readily fusible that splinters may be readily melted by being held in the flame of a candle, while bronzite is infusible. The others are of intermediate degrees of fusibility.

**117. Volatility.**—This is shown by heating fragments of minerals in *closed* or *open* tubes, or while resting upon pieces of charcoal or other “supports.” Some minerals are completely driven off in vapour by such treatment, while others are quite unchanged. Further reference to the fusibility and volatility of minerals will be made in the chapter on the use of the blowpipe.

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## CHAPTER XVIII.

### THE CHEMICAL CHARACTERS OF MINERALS—(*Continued*).

**118.** THE world and all it contains is made up of about sixty-two perfectly distinct substances. These are called elements by chemists, because hitherto they have not been able to *decompose* them, that is, to obtain from either of them two different kinds of matter.

Of this large number of elements, many are very rare, while the most common minerals are made up of little more than a dozen. Those elements which occur most frequently in mineral substances are the gases oxygen, hydrogen, nitrogen, chlorine, and fluorine; the non-metallic solids sulphur, carbon, silicon, and boron; and the metals potassium, sodium, lithium, calcium, magnesium, aluminium, and iron. Besides these the ores of lead, copper, tin, manganese, zinc, bismuth, antimony, arsenic, as well as of gold, silver, mercury, and platinum, are sought for by miners for the sake of the metals they contain.

119. Elements sometimes occur in a nearly pure state, when they are said to be *native*; thus, native sulphur occurs in the neighbourhood of many volcanoes, and native gold, silver, and copper, are not uncommon in certain districts. More usually, however, two or more elements are combined together, forming *compounds*. Water, tin-ore, and many other ores of the metals, when in a pure state, contain only two elements, other minerals contain three or four, while a few contain small quantities of many elements. These compounds are not mere mixtures, but quite distinct substances, having properties different from those of their constituents. Thus, water contains the two gases, *oxygen* and *hydrogen*; but the properties of water are quite different from those of oxygen, of hydrogen, or of any mere mixture of these gases.

The more commonly occurring natural compounds are *oxides*, *sulphides*, *chlorides*, *carbonates*, *silicates*, *sulphates*, *arsenates*, and *phosphates*. Oxides are compounds of oxygen with other elements; carbonates, silicates, sulphates, arsenates, and phosphates, contain besides oxygen, carbon, silicon, sulphur, arsenic, or phosphorus. Sulphides and chlorides contain no oxygen, but are compounds of chlorine or sulphur with various metals.

120. In chemistry, the elements are usually indicated by letters rather than by their full names. These *symbols*, as they are called, are found very convenient by those

who have once learnt their use. This forms an early stage in the study of the science of chemistry.

The symbols are frequently combined together into certain *formulae*, which very plainly indicate the composition of the substances to which they refer. It is found that elements only combine together in certain definite proportions, which are frequently called their atomic weights; or in multiples of these. In the following table of the elements, the symbols and atomic weights are placed against the names of the respective elements to which they belong. Those elements whose names are printed in large capitals, like IRON and OXYGEN, are of the greatest importance, and most of them are very abundant; others, such as BISMUTH and PHOSPHORUS, are of less importance; while the rest are either very rare or but little known. The rarest of all are not mentioned.

### TABLE OF THE ELEMENTS.

#### A.—METALS.

Name.	Symbol	Atomic or Unit Weight.
ALUMINIUM .....	Al.	27·5
ANTIMONY.....	Sb.	122·
ARSENIC .....	As.	75·
Barium .....	Ba.	137·
BISMUTH .....	Bi.	208·
Calcium .....	Ca.	40·
Chromium.....	Cr.	52·5
Cobalt .....	Co.	58·8
COPPER .....	Cu.	63·5
GOLD .....	Au.	197·
IRON .....	Fe.	56·
LEAD .....	Pb.	207·
MAGNESIUM .....	Mg.	24·
Manganese .....	Mn.	55·
MERCURY .....	Hg.	200·
NICKEL .....	Ni.	59·
PLATINUM .....	Pt.	197·
POTASSIUM .....	K.	39·
SILVER .....	Ag.	108·
SODIUM .....	Na.	23·
Tungsten .....	W.	184·
Uranium .....	U.	120·
ZINC .....	Zn.	65·

## B.—METALLOIDS.

Names.	Symbol.	Atomic or Unit Weight.
Boron.....	B.	11.
Bromine .....	Br.	80.
CARBON .....	C.	12.
CHLORINE .....	Cl.	35.5
Fluorine .....	F.	19.
HYDROGEN .....	H.	1.
IODINE .....	I.	127.
NITROGEN .....	N.	14.
OXYGEN .....	O.	16.
PHOSPHORUS.....	P.	31.
SULPHUR .....	S.	32.
Silicon .....	Si.	28.

121. In most descriptions of minerals, the chemical composition of pure specimens is indicated by a group of symbols combined into what is called a *formula*. Thus, cerussite or carbonate of lead has a composition indicated by the formula  $\text{PbCO}_3$ . From this formula, and by the aid of the column of atomic or unit weights in the above table of the elements, it is easy to calculate the *percentage composition*, or the proportion of lead, carbon, and oxygen, present in each hundred parts. We commence by putting down the atomic weight of each of these elements beside its own symbol, as under, only multiplying the atomic weight of oxygen by three, because three atoms or proportions are indicated in the formula :

$$\begin{array}{r}
 \text{Thus, Pb} = 207 \\
 \text{C} = 12 \\
 \text{O} = 16 \times 3 = 48 \\
 \hline
 \text{Total,} \quad 267
 \end{array}$$

This tells us that 267 parts of a pure specimen of carbonate of lead contain neither more nor less than 207 parts of lead, 12 of carbon, and 48 of oxygen, and we may easily obtain the required percentage composition by means of three easy sums in simple proportion, as follows :—

As 267 : 207 :: 100 : 77·52 the percentage of Lead.  
 267 : 12 :: 100 : 4·49 the percentage of Carbon.  
 267 : 48 :: 100 : 17·97 the percentage of Oxygen.

Ans. Lead, 77·52.  
 Carbon, 4·49.  
 Oxygen, 17·97.

Total, 99·98.

In a similar manner any such problem may be readily solved.

## CHAPTER XIX.

### OF THE BLOWPIPE AND THE MODE OF USING IT.

122. THE blowpipe is a cheap and very convenient instrument, which is much used by mineralogists for directing the flame of a lamp or candle, and of concentrating its power upon a mineral, so as to ascertain the effect of heat upon it. A very convenient form of blowpipe is that of Dr. Black, shown in fig. 156. In its cheapest form it is made of japanned tin, and may be obtained for a few pence. In using the blowpipe it is necessary to *breathe* and *blow* at the same time, so that the operator may not have to interrupt the flame in order to take breath, as some operations require a continued blast for a considerable period of time. This, which at first seems difficult, will soon be acquired by proper practice. The student should at first practise breathing strongly inwards and outwards through the nostrils

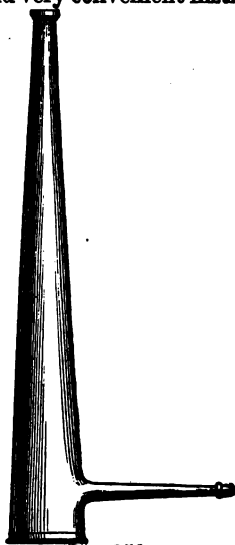


Fig. 156.



keeping his cheeks inflated the while, to their fullest extent. He should now put the blowpipe to his mouth, and after a little practice he will find no difficulty in breathing as before. At the same time, by slightly contracting the muscles of his cheeks, he will be able to force a thin and uninterrupted stream of air through the blowpipe, and the whole difficulty will be conquered. When the mouth is thus nearly emptied, it should be filled from the lungs with a portion of the air which otherwise would be expelled through the nostrils. Beginners usually blow for a longer or shorter period from the lungs alone, but this mode of blowing is by many thought to be injurious to the health. A beginner in the use of the blowpipe should therefore adopt the practice of breathing regularly and *audibly* through the nose, keeping up his blast by means of the muscles of the cheeks, and continue this until he is able to do so without perceptible exertion.

123. A lamp with a large wick, so as to give a broad flame, and fed with olive oil, is best, but a thick candle is more convenient for travelling. Many persons prefer to use gas, from its greater cleanliness, but it is not so good for a "reducing" flame. If the lamp or candle be used, the wick should be bent in the direction in which the flame is to be blown.

The flame is a more or less regular cone, yellow outside and pale blue inside. The heat is most intense just at the point of the blue cone, and a good experimentalist will be able to fuse a fine platinum wire by using this part of the flame, besides securing a constant and regular blast. The outer is called the oxidising, and the inner the reducing, flame.

The principal point to be attended to in the production of a good blowpipe flame is, that it be properly directed and applied. The chemical action of the flame is different according to the manner in which it is used, so that it is of the utmost importance that the student should become completely master of his flame.

124. In order to obtain a good *reducing* flame, the nozzle of the blowpipe should be made to touch the outer surface of the flame, just above the wick, and a *gentle* blast of air directed a little downwards. In this manner a bright yellow cone of flame will be produced, scarcely different from the original flame, except in direction. This bright yellow flame is not sufficiently supplied with oxygen for complete combustion, so that it has a tendency to take it from any oxidised substance placed within it, or to *reduce* such substances. Hence it is called the *reducing* flame.

125. To produce the oxidising flame, the nozzle of the blowpipe is introduced a little way into the flame, and a somewhat stronger blast is sent through it. The flame so produced should be of a very pale blue colour, almost invisible by daylight. In the oxidising flame all the oxygen required for complete combustion is supplied by the breath, so that there is no tendency to abstract any from substances placed within it. On the other hand,

these substances, being strongly heated, are in a favourable condition for taking up oxygen from the air, and accordingly many of them do so. Although the flame, therefore, is called an oxidising flame, it does not really *impart* oxygen to any substance, but simply puts it into a favourable condition for abstracting oxygen from the air. The reducing flame, on the contrary, does really *abstract* oxygen from the substance under treatment.

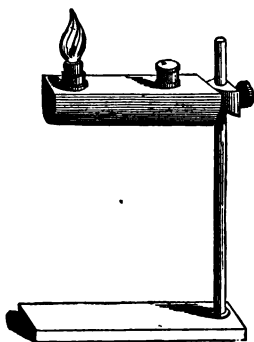


Fig. 157.

A cheap and convenient form of oil lamp for blowpipe operations is shown in fig. 157.

## CHAPTER XX.

## OF THE BLOWPIPE REACTIONS OF MINERALS.

**126.** THE complete blowpipe examination of a mineral consists of eight or more distinct operations, some of which may, however, sometimes be omitted, without much loss, after a little experience has been acquired. The fragment of mineral operated upon, called the "assay," should not generally be larger than a mustard seed, a small assay being much more manageable than a larger piece.

**127. FIRST OPERATION.**—The assay is placed in a small tube of glass sealed at one end, as shown in fig. 158. Such tubes may be made, after a little practice, from longer pieces of plain tubing, by melting the middle over a spirit-lamp or gas flame, and drawing the ends asunder. The tube successively assumes the appearances shown in *a*, *b*, *c*, fig. 159. Such tubes are called "ignition tubes," "matrasses," or "closed tubes." The closed tube must be clean and dry; the assay being placed in it is heated by means of a spirit-lamp, or the flame of a "Bunsen's burner," so that no coating of smoke may be deposited on the outside. The assay should be heated gradually, the better to see the changes produced. At the close of the operation the flame may be urged by the blowpipe, if little or no change has been observed. The changes to be looked for are:—



*a. Changes of colour.*—Many mineral substances change colour when heated in the Fig. 158. matrass, such as the arseniates and phosphates of copper, but these usually give off moisture as well. Carbonate of iron or *chalybite* turns black when heated, and becomes magnetic. In this manner it may be readily distinguished from dolomite, which it sometimes much resembles.

*b. Decrepitation.*—The assay flies to pieces with a crackling noise. This is often observed when *wolfram*, *blende*, and other mineral substances are strongly heated in the closed tube.

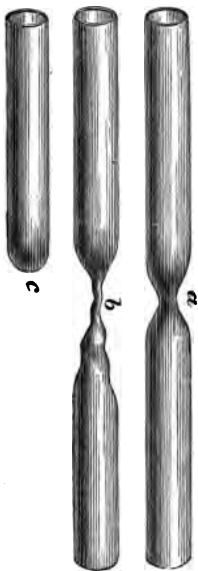


Fig. 159.

*c. Deposition of moisture on the cool part of the tube.*—This is a ready mode of distinguishing between *hydrous* and *anhydrous* minerals; thus, red hematite gives off no moisture when so treated; brown hematite always gives off water, which condenses in drops.

*d. Formation of a sublimate or solid deposit on the cool part of the tube.*—This is observable in the case of sulphides, arsenides, and some other substances. The sublimate of arsenic is white or black, of sulphur yellow, of arsenic and sulphur together, yellow, red, or black.

*e. Evolution of a vapour or peculiar odour.*—When the odour is *sulphureous* or *alliaceous*, sulphur

or arsenic are indicated.

*f. Fusion of the substance.*—This will not happen with substances of a higher degree of fusibility than two in the "Scale of fusibility," p. 70.

**128. SECOND OPERATION.**—A new assay piece is placed in a tube about six inches long, which is open at both ends, the tube being held in an inclined position over the spirit-lamp flame. As before, the flame may be urged by the blowpipe towards the close of the experiment. The effects to be noted are the same as in the first operation, but the sublimes will sometimes be different, and the odours more distinct.

**129. THIRD OPERATION.**—A little of the coarsely

powdered mineral is placed upon the surface of a piece of charcoal, in a small cavity scooped out for the purpose with a penknife. The *oxidising* flame is then directed upon it, and the effects noted.

*a. Degree of fusibility.*—This should be compared with that of fragments of a similar size from the scale of fusibility.

*b. Evolution of vapour or odour.*—This will usually be like that observed in the second operation.

*c. Deposition of a coating or incrustation on the cool part of the charcoal.*—This will usually be much like that observed in the second operation, but often much more distinct.

Those most likely to be observed are :—

*White*, near the assay, garlic odour, indicating *arsenic*.

*White*, farther from the assay, little or no odour, *antimony*.

*White*, yellow while hot, malleable bead of metal in fifth operation, *tin*.

*White*, yellow while hot, no bead in fifth operation, *zinc*.

*Yellow or orange*, malleable bead in fifth operation, *lead*.

*Yellow, red, or brown*, brittle bead in fifth operation, *bismuth*.

*Dark red*, white malleable bead in fifth operation, *silver*.

*d. Reduction to a bead of metal.*—This may occasionally happen with certain ores of gold or silver.

*e. A non-volatile residue remains.*—This may be tested by the fourth or fifth operations.

*f. Tinging of the tip of the flame.*—This may indicate various substances, thus :—

*Arsenic*, sulphur, and certain ores of copper tinge the flame *blue*.

*Barium*, phosphorus, borax, and certain ores of copper may tinge it *green*.

*Lithia*, *strontia*, or lime may give a *red* tinge.

Potash may give a *violet* tinge.

Soda may produce a *yellow* tinge.

These results will be better seen in the eighth operation.

**130. FOURTH OPERATION.**—If the residue from the third operation (*e*) is white, moisten it with a simple drop of solution of nitrate of cobalt, and heat it again strongly. Should it turn *green*, zinc is probably present; *blue*, alumina is indicated; *red* or *pink*, magnesia is present.

If in this second strong heating a bright and intense glow is observed, it will probably indicate either strontium, lime, magnesia, or zinc.

**131. FIFTH OPERATION.**—If the residue from the third operation (*e*) be any other colour than white, add a little carbonate of soda, and heat strongly with the *reducing* flame. The result to be looked for is the production of a bead of metal—in obstinate cases a little borax or cyanide of potassium may be added. If the portions of reduced metal be very small, they may escape observation; in this case the portion of charcoal around the assay should be cut out, ground up with water in a little mortar, and the light carbon and soluble soda washed away. Any shining particles of metal may then be readily detected.

The metals discovered may be recognised by their properties; thus, *gold* will be yellow and malleable; *silver* and *tin*, white and malleable; *copper*, red and malleable; *lead*, grey and malleable; *bismuth*, grey and somewhat brittle; *antimony*, grey and very brittle.

**132. SIXTH OPERATION.**—Make a small loop in the end of a platinum wire, heat it in the flame of the spirit-lamp, dip it into powdered borax, hold it again in the clear flame until the borax has melted into a clear, glassy bead, add to it a very little of the fine powder of the substance to be tested, heat it again, put in the *oxidising*, then the *reducing* flame. If no distinct colour is produced, take a little more of the assay on the same bead of borax and heat again. Do this several times if necessary. Should

a distinct colour be produced, it will probably be one of the following:—

*Blue* in both flames, indicating cobalt.

*Green* in both flames, indicating chromium.

*Green* in oxidising, *red* and *opaque* in reducing flame, copper.

*Violet* or *amethystine* in oxidising, *colourless* in reducing flame, manganese.

*Reddish-yellow*, oxidising, *dirty bottle-green*, reducing flame, iron.

**133. SEVENTH OPERATION.**—Repeat the sixth experiment, using microcosmic salt instead of borax. The results will be generally the same, but the colours will be sometime smore delicate. By means of this experiment, too, *silica* may be readily detected, as it will not dissolve in a bead of microcosmic salt, but will remain in the bead unchanged as to form.

**134. EIGHTH OPERATION.**—Hold a new assay piece by means of a pair of platinum pointed forceps, or a piece of platinum wire tightly twisted round it, in the top of the oxidising flame. Observe any change of tint, as mentioned in the third experiment. This experiment, too, will afford a convenient opportunity of determining the degree of fusibility of the specimen, as it may be compared with similar fragments from the scale of fusibility.

The eighth operation is of the greatest use in the absence of such substances as give sublimes, incrustations, or coloured beads in the first seven experiments. When, however, such results have been already observed, the eighth experiment should be omitted, as the platinum is liable to be injured.

## CHAPTER XXI.

### OF PSEUDOMORPHOUS MINERALS.

**135.** THESE are substance swchich have the *form* of one  
13 E F

mineral and the *composition* of another. They are the products of natural changes quite similar to those produced by the petrifying springs so common in some districts, or to those which shells and bones undergo in being changed into fossils while imbedded in the rocks.

a. Some pseudomorphs are formed by the removal in some way of a portion of the original while still in the earth, the removal having been so slow as not to change the form of the mineral. Thus, crystals of *quartz* are occasionally found having the form of *stilbite*, the water, alumina, and lime of the stilbite having been in some way removed without changing its form. This is called pseudomorphism by *loss* of ingredients.

b. Sometimes *limonite* is found in the form of *hematite*. Here the original hematite has taken up a quantity of water without suffering any change of form. This is called pseudomorphism by *gain* of ingredients.

c. Sometimes galena occurs in the perfect form of phosphate of lead or *pyromorphite*. In this case the phosphoric acid of the pyromorphite has been in some way exchanged for the sulphur of the galena. This is called pseudomorphism by *exchange* of ingredients.

d. Occasionally no one ingredient of the original remains. Thus *graphite* has been found in the form of *pyrites*. This is called pseudomorphism by total change of substance.

e. Sometimes dimorphous substances suffer similar changes. Thus *calcite* has been found having the form of *aragonite*. This is called pseudomorphism of dimorphous substances.

f. Sometimes a fossil shell or bone is found completely changed into some mineral substance, but still retaining its original form and structure. Thus *ammonites* are often found converted into *pyrites*, and *wood* into *opal*. This is called pseudomorphism after organic forms.

g. Some pseudomorphs are formed by incrustation of other substances, as *moulds* on their surface. This is a very common form of pseudomorph. Such pseudomorphs



are often hollow, and sometimes contain fluids when first discovered. Thus, beautiful cubes of *chalybite* have been found at Virtuous Lady Mine in Devon, which were evidently formed on the surface of large cubes of *fluor*, which have been subsequently removed.

*h.* Pseudomorphs are occasionally formed by infiltration, as *casts*, within such hollow moulds as have been just described. Thus some of the hollow octohedrons of *quartz*, which were discovered many years ago at the Consolidated mines in Cornwall by Mr. R. W. Fox, and which had evidently been deposited upon octohedrons of *fluor*, were discovered partly filled up with quartz; and some solid octohedrons of quartz were found at the same time which had been evidently formed in the same manner.

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## CHAPTER XXII.

### OF THE DISTRIBUTION AND PARAGENESIS OF MINERALS.

**136. Distribution.**—Of the more common or important minerals described in the second part of this work, many have been found in almost all parts of the world. Some few, however, are much less widely distributed, having only occurred in a few localities; and there are many of the rarer minerals which have only occurred hitherto at some one locality. Thus, the *diamond*, *corundum*, *idocrase*, *spinel*, *labradorite*, *sassolite*, *borax*, *sal-ammoniac*, *cinnabar*, *mercury*, *platinum*, and many others which might be mentioned, are not known to have occurred in the British islands, and many other minerals which are even very common in some countries, are here quite unknown. On the other hand, several minerals have been found in England, especially in Cornwall, which have never yet been found elsewhere.

**137.** In Cornwall itself, the chief mineral district in Great Britain, several minerals have only occurred in one,

others in two or three localities ; some have been found only in the east, others only in the extreme west ; some only in granite, others only in greenstone, others in slaty or porphyritic rocks.

**138. Paragenesis.**—It is well known that certain minerals are commonly associated with others in lodes or other mineral deposits. To this association the name of paragenesis has been given. Sometimes the expression is intended to refer to groups of minerals which occur near to each other, or are “congenial” to each other, as miners say ; but a more strict paragenesis would deal with those groups of minerals which are in contact with each other, or which are even imbedded in or surrounding others.

We shall only here refer to a few of the better known examples of paragenesis :—

*Quartz* is often associated with orthoclase, mica, schorl, chlorite, chalybite, calcite, dolomite, barytes, fluor, cassiterite, pyrites, chalcopyrite, limonite, goethite, wolfram, cuprite, copper, galena, blende, bournonite, etc.

*Cassiterite* is often associated with quartz, schorl, chlorite, mispickel, pyrites, blende, etc.

*Chalcopyrite* is often associated with quartz, fluor, galena, blende, chalybite, dolomite, pyrites, etc.

*Galena* is often associated with quartz, pyrites, chalcopyrite, blende, etc.

*Pyrites* often occurs with quartz, cassiterite, chalcopyrite, galena, fluor, mispickel, limonsite, etc.

*Cuprite* occurs with quartz, copper, malachite, chessylite, etc.

*Fluor* occurs with quartz, wolfram, chlorite, orthoclase, chalybite, etc.

*Serpentine* occurs with steatite, diallage, asbestos, copper, chrysocolla, etc.

## CHAPTER XXIII.

## OF THE CLASSIFICATION OF MINERALS.

139. MANY different modes of classifying minerals, for convenience of study, have been proposed at different times. The magnificent collection of minerals at the British Museum is arranged according to the chemical composition of the substances; thus, the carbonates, sulphides, oxides, and silicates are brought together into distinct groups, which are further subdivided by the separating of the *hydrous* from the *anhydrous* minerals of each group. This may be called the **Chemical** arrangement.

140. The system in use at the Museum of Practical Geology in Jermyn Street is also a chemical system, but it differs somewhat from the former in bringing all the ores and combinations of one metal into one group. As this method is very convenient for those who are concerned in manufactures, it has been called the **Economical** arrangement.

141. Several German mineralogists have endeavoured to group together such minerals as have a considerable similarity in physical as well as in chemical characters; thus, those sulphides which much resemble *pyrites*, such as marcasite, cobaltite, smaltite, mispickel, etc., have been called the **pyrites** family; others, which resemble zinc and blende, are called the **blende** family. In the second part of this book, the minerals described are arranged upon the second of these systems, that in use in Jermyn Street, except that the silicates are arranged in natural groups more in accordance with the German methods.

142. The minerals are first separated into two great divisions, called **Non-Metallic** and **Metallic**. These names are convenient, but not strictly accurate, as the non-metallic division includes many minerals which contain *potassium*, *sodium*, *calcium*, and other metals of the

alkalies and alkaline earths. In some cases, too, they contain small quantities of the ordinary heavy metals.

As a rule, with very few exceptions, the metals of the non-metallic division have a non-metallic lustre—a streak the same as or lighter than the colour, which is very variable, and a specific gravity under 5, often under 3.

The metallic division includes those minerals which consist, to a great extent, or chiefly, of the true heavy metals. They have frequently a metallic lustre; the specific gravity is often over 5, and the streak is frequently darker than the colour, which is mostly constant or characteristic.

**143.** The first or **Non-Metallic** division includes five classes.

The first class includes the minerals, which consist chiefly of *carbon* and *boron*.

The second class includes the minerals, which consist chiefly of *sulphur* and *selenium*.

The third class includes a large group of carbonates, sulphates, chlorides, and other combinations, chiefly of the alkalies and alkaline earths, called *haloids* and *salts*.

The fourth class consists of the earths *silica*, *alumina*, and *magnesia*.

The fifth class consists of *silicates* and *aluminates*.

Each of these five classes, which are of very unequal extent, are further subdivided into groups; some of large, others of smaller extent.

**144.** The second or **Metallic** division is divided into four groups or classes.

The first class includes those minerals which contain the brittle and difficultly fusible metals, such as manganese and wolfram.

The second class includes those minerals which contain the brittle, easily fusible, and volatile metals, such as arsenic, antimony, and bismuth.

The third class includes those minerals which contain the ordinary malleable metals, whose oxides cannot be

reduced by heat without fluxes, such as iron, copper, tin, and lead.

The fourth class includes those minerals which contain the "noble" metals, whose oxides are reducible by heat alone, such as gold, silver, and mercury.

145. The following abbreviations of terms frequently used will be found in the descriptions of the more common minerals in Part II. :—

H for Hardness.

G for Specific Gravity.

Fus. for Fusibility.

O F for Oxidizing Flame.

R F for Reducing Flame.

H Cl. for Hydrochloric Acid.

H N O<sub>3</sub> for Nitric Acid.

H<sub>2</sub> S O<sub>4</sub> for Sulphuric Acid.

K H O for Solution of Caustic Potash.

Co for Solution of Nitrate of Cobalt.

Sol. for Soluble.

Insol. for Insoluble.

Soda for Carbonate of Soda.

Micro. for Microcosmic Salt.

Comp. for Chemical Composition.

B. etc. for Blowpipe and other Reactions.

Loc. for Localities.

Var. for Varieties.

## PART II.

### BRIEF DESCRIPTION OF SOME OF THE MOST IMPORTANT MINERALS.

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#### DIVISION I.—NON-METALLIC MINERALS.

(Generally non-metallic lustre, streak the same as or lighter than colour, specific gravity under 5, often under 3. Colours very variable in the same mineral.)

CLASS I.—CARBON AND BORON.

CLASS II.—SULPHUR AND SELENIUM.

CLASS III.—HALOIDS AND SALTS.

CLASS IV.—EARTHS.

CLASS V.—SILICATES AND ALUMINATES.

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#### CLASS I.—CARBON AND BORON.

##### CARBON GROUP.

1. **Diamond.**—*Cubical.*  $H = 10$  ;  $G = 3.5$  ; lustre adamantine ; usually transparent and colourless, but occasionally coloured yellow, blue, or black. Cleavage very perfect, parallel to *o*. Crystals as above, figs. 38, 41, 43, etc., the planes often curved.

*Comp.*—C. The diamond is almost chemically pure carbon.

*B. etc.*—In OF it burns away very slowly ; not affected by acids ; the hardest substance known.

*Loc.*—Minas Geraes in Brazil and other parts of South

America; Golconda and other places in the East Indies; South Africa, etc. The finer specimens are used for ornament; imperfect specimens, as well as those of a dark opaque kind, called boart, are valuable for glass cutting, engraving, and rock boring.

**2. Graphite** [Plumbago, Black Lead].—*Hexagonal*.  $H = 1$ ;  $G = 2$ ; lustre metallic; usually dark lead-grey, and quite opaque; streak black and shining; crystals very rare. Crystals like fig. 111, but rare; the prisms usually very short. Cleavage very perfect, parallel to O P. Soils paper, and feels greasy.

*Comp.*—C. Graphite is tolerably pure carbon, but usually contains a small proportion of iron.

*B. etc.*—In O F burns away slowly, leaving a little grey or red ash; not affected by acids.

*Loc.*—Borrowdale in Cumberland, Arendal in Norway, in Canada, and in many other places. The finer specimens are used for making black lead pencils; the coarser varieties for making crucibles.

**3. Coal.**—*Amorphous*.  $H$  from 2 to 2.5;  $G$  from 1.3 to 1.5. It is more or less impure carbon, combined with oxygen and hydrogen. It occurs in beds, sometimes of great extent and thickness, but is rather a rock than a mineral. All its varieties consist of altered vegetable matter, with occasionally a little animal matter. It is found in large quantities in the north of England and in South Wales, as well as in North America and many other places. The chief varieties are:—

*Anthracite.*—A hard and shining variety, very valuable for steam coal and smelting purposes.

*Caking Coal.*—The ordinary kinds of house coal.

*Cannel Coal.*—A smooth and compact variety, of great value for gas making.

*Lignite* or Brown Coal.—A less altered kind, retaining much of the original woody structure.

*Jet.*—A very compact variety of lignite, somewhat approaching to cannel coal, much used for ornamental purposes.

**4. Bitumen.**—*Amorphous*.  $H = 0$  to  $2$ ;  $G = 0.75$  to  $1.2$ .

*Comp.*—The different varieties of bitumen consist of carbon combined with hydrogen in varying proportions. All are highly combustible.

*Loc.*—It occurs in a fluid form, as naphtha or petroleum, in Persia and North America. The more solid pitchy forms occur at Trinidad and other places. Small quantities of bitumen in a solid form, called mineral pitch, have occurred in some of the mines of Cornwall, and an elastic kind, called elaterite, is found in Derbyshire.

**5. Amber.**—*Amorphous*.  $H = 2$  to  $2.5$ ;  $G = 1$  to  $1.1$ ; usually yellow, and nearly or quite transparent.

*Comp.*—It consists of carbon combined with oxygen and hydrogen, and is highly combustible. It is a mineralised resin, and therefore not a true mineral.

*Loc.*—It occurs in beds on the northern shores of Prussia, and is occasionally washed up on to the beach in the east of England.

## BORON GROUP.

**6. Sassolite** [Sassolin; Boracic Acid].—*Anorthic*.  $H =$  about  $1$ ;  $G = 1.5$ ; white or pale yellow; crystals very rare; usually occurs in thin scales, which feel greasy.

*Comp.*—Nearly pure boric or boracic acid.

*B. etc.*—When heated, it melts to a glassy bead, colouring the flame green. If dissolved in alcohol, it imparts a green tinge to its flame when burnt.

*Loc.*—It occurs in the waters of certain lakes in Tuscany, and in Atacama on the western coast of South America, as well as in other volcanic districts. The pale yellow tinge is due to sulphur, which is usually present with it in small quantity.

**7. Borax** [Tincal].—*Oblique*.  $H = 2$  to  $2.5$ ;  $G = 1.7$ ; white and semi-transparent or opaque; lustre vitreous.

*Comp.*—Hydrated borate of soda, having when pure



the composition represented by the formula  $\text{Na}_2 \text{B}_4 \text{O}_7 + 10 \text{H}_2 \text{O}$ .

*B. etc.*—When heated swells up and becomes opaque, but afterwards melts to a clear transparent globule.

*Loc.*—Thibet, in Central Asia; Potosi, in South America, and other places, where it occurs in loose crystals imbedded in clay, sometimes associated with rock salt. When purified by a re-crystallization, it is a valuable re-agent for blowpipe experiments, as it forms beads of characteristic colours with various metallic oxides (see p. 80). In South America, where it is rather abundant, it is sometimes used as a flux in smelting copper ores.

## CLASS II.—SULPHUR AND SELENIUM.\*

**8. Sulphur** [Native Sulphur].—*Rhombic*.  $H = 1.5$  to  $2.5$ ;  $G = 2.0$ ; usually yellow, with resinous lustre; transparent to translucent. It frequently occurs in crystals, more or less resembling fig. 86, reniform and stalactitic masses, or as a thin crust on other minerals.

*Comp.*—Sulphur almost or quite pure.

*B. etc.*—Burns entirely away with a blue flame and strong sulphureous odour.

*Loc.*—Sicily, Naples, and other localities, often in connection with active or extinct volcanoes.

**9. Selen-Sulphur.**—This is a brownish kind of sulphur, found on the island of Vulcano in the Mediterranean, which contains a considerable proportion of *selenium*.

**10. Native Selenium** has been found in Mexico, but is very rare, and but little known. It is of brownish-black or lead-grey colour, about as hard as sulphur, but much heavier.

\* This Class contains but very few minerals, and is separated from Class I. on purely chemical grounds.

## CLASS III.—HALOIDS AND SALTS.

## ALKALI GROUP.

*(Ammonia, Potash, and Soda).*

**11. Sal Ammoniac.**—*Cubical.*  $H = 1.5$  to  $2.0$ ;  $G = 1.5$ ; crystals very rare; usually white or yellowish.

*Comp.*—More or less impure chloride of ammonium,  $NH_4 Cl$ . It has a peculiar saline and pungent taste, and is readily soluble in water.

*B. etc.*—When heated in the closed tube, sublimes without previously fusing; heated with caustic lime, potash, or soda, gives off the pungent odour of ammonia.

*Loc.*—It occurs at Etna, Vesuvius, and other volcanoes, often associated with sulphur, but not in any great quantities.

**12. Kalinite** [Alum].—*Cubical.*  $H = 2$  to  $2.5$ ;  $G = 1.8$ ; usually white or transparent, and colourless, with a vitreous lustre. Natural crystals are somewhat rare, but fine artificial crystals are common, and easily prepared. They are usually octahedrons, often more or less imperfect or maced, as shown in figs. 38, 133, 134.

*Comp.*—Hydrated sulphate of potash and alumina; its formula may be written  $Al_2 K_2 (SO_4)_4 + 24 H_2 O$ , or more simply  $(Al K) SO_4 = 6 H_2 O$ . It may be readily known by its peculiar and well known sweetish-astringent taste.

*B. etc.*—When heated in the closed tube, it at first melts readily, swells up, and gives off much water, afterwards changes to a nearly infusible white mass. There are several varieties of alum known—containing soda, ammonia, iron, and other substances in place of the potash; but these are all very rare.

*Loc.*—It occurs in small quantities in fissures in many volcanic districts; but is mostly extracted from alum clays, as at Whitby, Paisley, and other places in the north of England.

**13. Nitre.**—*Rhombic.*  $H = 2$ ;  $G = 2$ . Natural crys-

tals are somewhat rare, the mineral occurring chiefly as a crust on old walls and rubbish heaps. Fine artificial crystals often occur in hexagonal prisms, which are macles composed of six rhombic prisms, the same as occur in aragonite, with which nitre is *isomorphous*.

*Comp.*—Anhydrous nitrate of potash,  $\text{K N O}_3$ . It has the cool, saline, and somewhat bitter taste of saltpetre. It is readily soluble in water.

*B. etc.*—When thrown on red hot charcoal, or in a fire, it deflagrates. Paper soaked in a strong solution of nitre and dried, is converted thereby into touch-paper, which burns with a violet coloured flame.

*Loc.*—It occurs on limestone in the caves of Apulia, in Malta, and in other parts of Europe. Large quantities of it are prepared artificially for glass-making, medicine, and the manufacture of gunpowder.

**14. Nitratite** [Nitratine, Nitrate of Soda].—*Hexagonal*.  $\text{H} = 2$ ;  $\text{G} = 2$ ; colourless and transparent when pure, but often tinged yellow or brown. The mineral occurs chiefly as an efflorescence, but natural crystals are sometimes found. Lustre vitreous.

*Comp.*—Anhydrous nitrate of soda,  $\text{Na N O}_3$ . It has a cool, somewhat bitter taste, dissolves readily in water, and is very deliquescent.

*B. etc.*—Like nitre, but colours the blowpipe flame strongly yellow.

*Loc.*—It is found encrusting the soil, and on stones and old walls, in Chili and Atacama. It is much used in the manufacture of nitric acid.

**15. Halite** [Rock Salt].—*Cubical*.  $\text{H} = 2$ ;  $\text{G} = 2.2$ ; colourless and transparent when pure, but usually tinged yellow, brown, blue, or green. It is frequently found crystallized in cubes and octahedrons, as shown in figs. 38, 39, 135, and has a very perfect cleavage parallel to the faces of the cube. Lustre vitreous.

*Comp.*—Anhydrous chloride of sodium. It dissolves readily in water, is often deliquescent, and may be readily known by its taste.

*B. etc.*—Often decrepitates when heated, and tinges the blowpipe flame yellow.

*Loc.*—It is abundant at Northwich and other places in Cheshire, where it is mined for agricultural purposes. It also occurs in great purity in the salt mines of Hungary and Transylvania, as well as in many other places.

#### ALKALINE EARTH GROUP.

(*Baryta, Strontia, Lime, Magnesia.*)

**16. Barytes** [Heavy Spar].—*Rhombic*.  $H = 3$ ;  $G = 4.3 - 4.7$ ; sometimes colourless and transparent, but often tinged yellow or brown. Crystals common, and often of large size, in forms resembling figs. 94, 95, 97. Cleaves perfectly and easily, parallel to the faces  $OP$  and  $\infty P \infty$  at right angles to each other. Sometimes a third less perfect cleavage parallel to  $\infty \bar{P} \infty$ . Frequently occurs, too, in radiated or fibrous masses. Lustre vitreous.

*Comp.*—Anhydrous sulphate of barium,  $BaSO_4$ . It is insoluble in water and acids.

*B. etc.*—Decrepitates strongly, and fuses on thin edges, with some difficulty, colouring the flame yellowish green.

*Loc. and Var.*—*Bolognese stone* is a peculiar radiated form occurring at Bologna, which shines with a phosphorescent light when placed in a dark room after being exposed to the rays of the sun or heated.

*Cawk* is a massive variety occurring in Derbyshire, Staffordshire, and Scotland.

Very fine crystals of Barytes occur at Dufton in Cumberland, in Bohemia, Hungary, and the United States. It is used for making paint as a substitute for white lead, and is a violent poison.

Beautiful crystals were formerly found at the United Mines in Gwennap and Huel Mary Ann, near Liskeard, both in Cornwall.

**17. Witherite.**—*Rhombic*.  $H = 3$  to  $3.5$ ;  $G = 4.2$  to  $4.3$ ; sometimes colourless and transparent, but usually white.

yellow, or brown. Crystals rare. Cleavage indistinct. Lustre vitreous.

*Comp.*—Anhydrous carbonate of barium,  $\text{BaCO}_3$ . Soluble, with effervescence, in  $\text{HCl}$  or  $\text{HNO}_3$ , when moderately diluted.

*B. etc.*—Fuses easily to a transparent globule, which becomes opaque when cold.

*Loc.*—It occurs at Alston Moor in Cumberland and in other parts of England, as well as in Hungary, Sicily, and many other foreign localities. It is very poisonous, and is sometimes used for poisoning rats.

**18. Celestite** [Celestine].—*Rhombic*.  $H = 3$  to  $3.5$ ;  $G = 4$ . Often colourless and transparent, but sometimes reddish, pink, or clear blue. Crystals not uncommon, a good deal like those of barytes. One perfect and one less perfect cleavage. Lustre vitreous.

*Comp.*—Anhydrous sulphate of strontium,  $\text{SrSO}_4$ . Insoluble in water, and scarcely at all soluble in acids.

*B. etc.*—Decrepitates and fuses easily to a milk-white globule, tinging the flame red, especially if moistened with  $\text{HCl}$ , after being exposed to the reducing flame.

*Loc.*—Fine crystals occur in the sulphur mines of Girgenti and other parts of Sicily, at Bex in Switzerland, and many other foreign localities, and beautiful colourless crystals in cavities in pink masses were found some years since at Aust Ferry, near Bristol. It is used in the preparation of nitrate of strontium, which is used in the manufacture of fireworks to give a red flame.

**19. Calcite** [Calc Spar, Carbonate of Lime].—*Hexagonal*.  $H = 3$ ;  $G = 2.7$ . Colourless and transparent when pure, but frequently white and translucent to opaque, or tinted yellow, red, brown, etc. Crystals very common, and of very many distinct forms; some of those more usually occurring are shown in figs. 111, 114, 115, 116, 118, 122, 124, 151. Cleavage perfect and easily obtained, parallel to the faces of the chief rhombohedron *R*. Lustre vitreous.

*Comp.*—Anhydrous carbonate of lime,  $\text{CaCO}_3$ . Dissolves readily with effervescence in dilute  $\text{HCl}$ .

*B. etc.*—Infusible, but becomes caustic by strong heating, tinging the flame dull brick red.

*Loc. and Var.*—*Iceland spar*, or *double refracting spar*, is a very pure variety from Iceland, which cleaves readily into rhombs.

*Dogtooth spar* is a variety composed of small scalenohedrons projecting from a compact mass. Fine specimens occur near Bristol and in many other limestone districts.

*Schiefer spar* is a variety occurring in very thin plates or scales. It occurs at Botallack mine in Cornwall, and in many other localities.

*Marble* is a massive granular variety. The finest specimens are found in Italy and Greece, and are pure white.

*Stalactite* and *stalagmite* are varieties formed by deposit from water containing lime in solution. They are found very frequently in caves in limestone countries, especially in Derbyshire.

*Oolite* is composed of small rounded concretions. It is abundant near Bath, where it is known as Bath Stone.

*Pisolite* is simply oolite, in which the concretions are very large.

*Swinestone* is a variety of marble which gives off a fetid odour when broken or rubbed.

*Limestone* is a granular variety which is much used for burning into lime for building and agricultural purposes, and also as a building stone.

*Chalk* is an earthy variety made up of fragments of minute shells, etc. It forms great hills in the east and south of England, and in other places. Many other varieties have received distinct names.

Some of the many forms of calcite occur in most mineral districts, and are frequently very common.

**20. Aragonite.**—*Rhombic*.  $H = 3.5$  to  $4$ ;  $G = 3$ . Colourless and transparent when pure, but often coloured yellow, brown, etc., like calcite. Crystals not uncommon,

in forms resembling fig. 111, which are macles consisting really of six rhombic prisms. The same form of macle occurs in witherite and in nitre. Lustre vitreous. Occurs also frequently in radiated or fibrous masses.

*Comp.*—Anhydrous carbonate of lime,  $\text{CaCO}_3$ , like calcite. It also dissolves readily in dilute  $\text{HCl}$ .

*B. etc.*—Infusible, but falls to powder when heated, in this differing from calcite. It often tinges the flame more brightly red than calcite, owing to the presence of a small proportion of strontia.

*Loc.*—Fine crystals are found at Aragon in Spain and in Bohemia. Globular concretions have occurred at St. Just in Cornwall, and satin spar, a fine fibrous variety, occurs at Dufton in Cumberland.

**21. Gypsum.**—*Oblique.*  $H = 1.5$  to  $2$ ;  $G = 2.3$ . When pure, colourless and transparent, but often grey, yellow, or brown. Massive varieties are often mottled or veined. Crystals, like figs. 100, 101, not uncommon, perfect, and easily obtained. Cleavage parallel to  $\infty P\infty$ . Lustre vitreous or pearly. Thin plates flexible, but not elastic.

*Comp.*—Hydrated sulphate of lime,  $\text{CaSO}_4 + 2\text{H}_2\text{O}$ . Slightly soluble in water and acids.

*B. etc.*—Becomes white and opaque, and at a high temperature fuses to a white enamel.

*Loc. and Var.*—*Selenite* is the crystallized variety which occurs abundantly in the clay of Shotover Hill near Oxford, at Chatley near Bath, at the Isle of Sheppey in Kent, and in many other localities.

*Fibrous gypsum* or *satin spar* occurs at Matlock in Derbyshire, and in many other places. It must not be confounded with the satin spar, which is a variety of aragonite.

*Compact gypsum* or *alabaster* is found of a beautiful white at Volterra in Tuscany. Less pure varieties occur at Montmartre near Paris, in Derbyshire, and in Cheshire. Satin spar and white alabaster are used for making statuettes and small personal ornaments; the less fine veined and mottled specimens, as ornamental stones for

halls, tables, and the like; while the coarsest varieties are burned into plaster of Paris. Gypsum is also used as a glaze for porcelain, in the manufacture of glass, and for agricultural purposes as a top-dressing for meadows.

**22. Apatite** [Phosphorite].—*Hexagonal*.  $H = 5$ ;  $G = 3$  to  $3.25$ ; lustre vitreous. Sometimes colourless and transparent, but usually grey or brownish. Crystals not uncommon in the form of figs. 111, 113, 118, 130, etc. Cleavages imperfect. The prismatic faces are often striated vertically.

*Comp.*—Anhydrous phosphate, with a little fluoride or chloride of lime. Its formula may be written  $3 Ca_3 (PO_4)_2 + Ca (F \text{ or } Cl)_2$ . It is soluble, but not very rapidly, in  $HNO_3$  or  $HCl$ .

*B. etc.*—Thin splinters may be melted with some difficulty into a colourless, translucent glass. With micro dissolves to a clear glass, which, if sufficiently saturated, becomes opaque on cooling, and presents crystalline facets. If moistened with  $H_2SO_4$  and heated, tinges the flame green or bluish green.

*Loc.*—Apatite occurs in very fine crystals occasionally at St. Michael's Mount and at Tremearne, in the cliffs of the Mount's Bay in Cornwall; at Bovey Tracey, Devon; and in many other localities. Very fine and large crystals have occurred at Hammond and Eden-ville in the State of New York.

*Francolite* is a variety containing fluorine instead of chlorine, which has been found at Huel Franco in Devon and Fowey Consols in Cornwall.

*Phosphorite* is a massive variety occurring in Rhenish Prussia, Estremadura in Spain, and other places, and is much used in the preparation of artificial manures.

**23. Fluor** [Fluor Spar].—*Cubical*.  $H = 4$ ;  $G = 3.2$ ; lustre vitreous; sometimes colourless and transparent, but more usually green, purple, yellow, or pink. Crystals like figs. 38, 39, 43, 44, etc., common, figs. 51 to 57, 59, 60, somewhat more rare. Perfect cleavage parallel to the faces of the octahedron,



*Comp.*—Anhydrous fluoride of calcium,  $\text{Ca F}_2$ . Slowly soluble in  $\text{H Cl}$  or  $\text{HNO}_3$ ; decomposed by  $\text{H}_2 \text{SO}_4$ , giving off vapours which have the power of etching or corroding glass.

*B. etc.*—Decrepitates, phosphoresces, and in thin splinters fuses to an opaque white mass, tinging the flame red.

*Loc.*—Fine crystals are common at Beeralston in Devon, and in many of the mines near Redruth and Liskeard in Cornwall. The finest crystals are, perhaps, from Alston Moor in Cumberland, and from some of the Derbyshire mines, especially near Castleton at the celebrated "Blue John" mine.

*Chlorophane* is a massive variety which shines with a bright green light when moderately heated. It occurs in white, nearly opaque, compact masses, at East Pool Mine, near Redruth, at Alston Moor, and in many other localities.

Fluor spar is called "Cann" by the Cornish miners, and "Blue John," or "Derbyshire spar," by those of Derbyshire and Cumberland. That from Derbyshire is much used for ornamental purposes, while the commoner kinds are used in the preparation of hydrofluoric acid for etching glass, and also as a flux in the smelting of ores.

**24. Magnesite.**—*Amorphous.*  $\text{H} = 3$  to  $5$ ;  $\text{G} = 2.8$  to  $3.0$ . Lustre vitreous or dull; white and opaque, or subtranslucent, but sometimes greyish or yellowish.

*Comp.*—Anhydrous carbonate of magnesia  $\text{Mg CO}_3$ . Insoluble in water, but soluble in  $\text{H Cl}$  with effervescence.

*B. etc.*—Infusible, but glows with an intense white light when strongly heated. If treated with cobalt solution and again heated, turns pink or red.

*Loc.*—It has been found in thin veins in the serpentine rocks of the Lizard district in Cornwall, but only in small quantities. The purest specimens are obtained in Silesia, Moravia, Castellamonte, near Turin, and other places on the continent of Europe, and near Baltimore, in America.

**25. Dolomite.**—*Hexagonal.*  $H = 3.5$  to  $4.5$ ;  $G = 2.9$ . Lustre pearly; sometimes colourless and transparent, but usually greyish or yellowish, and translucent to opaque. Crystals like figs. 114, 115, etc., much like those of calcite; perfect cleavage parallel to the faces of the rhombohedron. Faces of the crystals often curved.

*Comp.*—Anhydrous carbonate of lime and magnesia,  $\text{Ca CO}_3 + \text{Mg CO}_3$ . Soluble in  $\text{H Cl}$ , but not so readily as calcite.

*B. etc.*—Infusible, but glows with a bright light.

*Loc and Var.*—*Pearl spar* occurs in rhombohedrons having a pearly lustre. It is found at New Roseworn Mine, in Gwinear, at Botallack, and other mines in Cornwall, as well as at Alston Moor and the lead mines of Derbyshire.

*Bitter spar, brown spar,* and other varieties have also been distinguished by different mineralogists.

*Granular dolomite* forms mountain masses in the Alps, Apennines, and other mountain ranges of Europe, and large hills in Yorkshire and other parts of England. It is a valuable building stone.

## CLASS IV.—EARTHS.

### SILICA GROUP.

**26. Quartz [Spar].**—*Hexagonal.*  $H = 7$ ;  $G = 2.6$ . Lustre vitreous. Pure varieties are colourless and transparent, but specimens occur of almost all colours, and varying from transparency to opacity. Crystals occur in very many distinct forms, figs. 108, 119 are amongst the most common, figs. 114, 128, 149, 150 have also been observed. Crystals are usually striated transversely on the faces of the prism.

*Comp.*—Anhydrous silica,  $\text{Si O}_2$ ; insoluble in all acids except hydrofluoric.

*B. etc.*—Infusible; fuses readily with effervescence if mixed with soda.

*Loc and Var.*—*Rock crystal* is a colourless transparent variety occurring in fine crystals. It occurs in most mining and mountainous districts, but is rarely abundant. Rock crystals, according to their localities, are known as Cornish, Irish, Scotch, or Bristol diamonds. The lustre of the finest specimens is rather adamantine than vitreous, and approaches that of the diamond. They may, however, be readily distinguished from real diamonds by their difference of crystalline form, and their inferior hardness and specific gravity.

*Amethyst* is a purple or violet crystalline variety which occurs in many localities. Fine specimens have occurred at St. Just in Cornwall.

*Citrine* or *false topaz* is a yellow variety which sometimes occurs in fine crystals. It may be distinguished from the real topaz by the difference of crystalline form, want of cleavage, and inferior hardness.

*Ferruginous quartz* is reddish brown rather than yellow, and often nearly opaque. It is ordinary quartz much coloured with oxide of iron, of which it occasionally contains as much as 5 per cent.

*Cairngorm* or *smoky quartz* occurs also in crystals. Fine specimens of a smoke-brown colour, and perfectly transparent, occur in the Cairngorm Mountains in Scotland, and in small quantities in some of the Cornish mines.

*Morion* is a black crystallized quartz which occurs in the same localities as Cairngorm, of which it is perhaps an extreme form. It is frequently found in small crystals in the iron mines of Cornwall.

*Rose quartz* is a rare kind of a beautiful pink colour which has been also found in Cornwall. Large masses of rose quartz have been found in some parts of Germany.

*Milky quartz* is nearly opaque, and of the colour of milk; sometimes crystallized, but more often massive. It occurs in small quantities in many mines.

*Sugary quartz* is a granular and somewhat friable massive variety.

*Floatstone* is a cellular variety.

*Fibrous quartz* or *cross-course spar* is made up of a multitude of imperfect prisms pressed confusedly against each other side by side.

*Prase* is a dull green and massive variety.

*Jasper* is an opaque massive variety, coloured by oxide of iron or other foreign matter. It is sometimes banded of different colours, when it is called *riband-jasper*. Many other varieties of quartz have been distinguished by special names, but they are either of rare occurrence or of little importance.

**27. Chalcedony.**—*Amorphous*.  $H = 7$  ;  $G = 2.6$ . Lustre vitreous or waxy. Usually occurs in botryoidal, mammillary, or stalactitic forms.

*Comp.*—Anhydrous silica,  $SiO_2$ , the same as quartz. Like it, too, it is insoluble in acids, except hydrofluoric.

*B. etc.*—Like quartz.

*Loc. and Var.*—Chalcedony in very fine stalactites occurs in several of the mines of Cornwall ; formerly at North Pool and Trevascus, and recently at East Pool, and especially at Pednandrea, near Redruth. It is frequently milk-white, yellow, brown, or pale lavender-blue.

*Flint* appears to be a variety of chalcedony, having the same hardness, specific gravity, and chemical composition, etc., but it differs in some respects.

*Carnelian* is a beautiful pale reddish-yellow variety, which is much used for personal ornaments.

*Agate* is a complex stone composed of chalcedony, jasper, and sometimes ordinary quartz.

**28. Opal.**—*Amorphous*.  $H = 6$  ;  $G = 2$ . Lustre vitreous or waxy. Sometimes transparent and colourless, but frequently milky white, pale yellow, brownish-blue, or iridescent. Fracture very perfectly conchoidal.

*Comp.*—Hydrated silica, with a variable proportion of water,  $SiO_2 + H_2O$ . It is insoluble in acids, but dissolves more or less completely in  $KHO$  solution.

*B. etc.*—Infusible, but yields water if heated in a closed tube. Like quartz, it dissolves with effervescence if fused with soda.

*Loc. and Var.*—*Noble opal* is semi-transparent or translucent, of a milk-white, bluish, or yellowish white colour, and exhibiting a beautiful play of colours. The finest specimens come from Hungary and Mexico.

*Fire opal* is transparent or semi-transparent, usually red or yellow, and brilliantly iridescent. Fine specimens are brought from Mexico, but inferior specimens have been obtained from Botallack Mine in Cornwall.

*Hyalite* or *Muller's glass* is vitreous, transparent, and colourless; much like glass in appearance, but readily distinguished from it by its infusibility.

*Cacholong* is white and opaque.

*Hydrophane* is nearly opaque when dry, but if placed in water becomes nearly transparent.

*Common opal* is semi-transparent, and the colours are dull. It has occurred in several Cornish localities.

*Semi-opal* is similar, but less transparent, and with still duller colours.

*Ferruginous opal* (eisenkiesel or iron flint) is a highly ferruginous variety; usually red or brown.

*Wood opal* has the form and texture of wood, of which it is a highly silicified variety.

#### ALUMINA GROUP.

**29. Corundum.**—*Hexagonal*.  $H = 9$ ;  $G = 4$ . Lustre vitreous to adamantine. Sometimes colourless, but more usually red, blue, yellow, or brown; seldom any distinct cleavage; faces of the crystals (fig. 108) sometimes curved; very tough, and difficult to break.

*Comp.*—Anhydrous alumina,  $Al_2O_3$ . Insoluble in acids.

*B. etc.*—Infusible: the fine powder becomes blue if treated with Co.

*Loc. and Var.*—*Corundum* or *adamantine spar* occurs in

rough crystals or masses, with dull colours, and distinct, but not perfect cleavage. It occurs in Ceylon and other parts of Asia.

*Sapphire* is highly transparent, sometimes colourless, but usually of a fine blue tint. It is a most valuable gem.

*Ruby* is highly transparent, and of a fine red colour. Fine stones are very rare and precious. The finest rubies and sapphires are brought from Ceylon.

*Emery Stone* is a compact, coarse variety of much value as a grinding material for cutting precious stones. It is usually brown, but sometimes grey or indigo-blue, and is brought in large quantities from Naxos, Smyrna, and other places in Asia Minor and Greece.

#### MAGNESIA GROUP.

**30. Brucite.**—*Hexagonal*.  $H = 2$  ;  $G = 2.3-2.4$ . Lustre pearly ; sometimes in crystals, but more often in foliated masses of a white, green, or grey colour. Very perfect basal cleavage (O P). Thin laminae, flexible, but not elastic.

*Comp.*—Hydrated magnesia,  $Mg\ H_2\ O_2$ , or  $Mg\ O + H_2O$ . Easily soluble in acids.

*B. etc.*—Infusible, but glows with an intense white light when strongly heated. In closed tube yields water. Treated with Co turns pink or red.

*Loc.*—In thin veins in serpentine rocks in the Shetland Isles, also at Hoboken, New Jersey, U.S.

### CLASS V.—SILICATES AND ALUMINATES

#### SECTION I.—SILICATES.\*

##### FELSPAR GROUP.

(The feldspars all have a hardness near 6, or are scarcely

\* Many silicates are infusible when unmixed, but they may be readily fused on addition of a little soda.

scratched with a knife, specific gravity near 2.6, and two distinct (often perfect) cleavages forming right angles, or nearly right angles. They are anhydrous, and nearly or quite insoluble in acids. Not readily fusible. Lustre vitreous or pearly).

**31. Orthoclase** [Potash Felspar].—*Oblique*.  $H = 6$  ;  $G = 2.6$ . Crystals not uncommon, like the figs. 146, 147, etc. ; sometimes colourless and transparent, but more frequently pink, red, grey, or brown. Perfect cleavages parallel to the faces *My* forming right angles.

*Comp.*—Anhydrous silicate of alumina and potash, with excess of silica. Insoluble in acids.

*B. etc.*—Fusible at about 5 ; tinges the flame violet.

*Loc. and Var.*—Adularia is a clear transparent variety which occurs in fine crystals in the Alps at St. Gothard, and also in Cornwall at Tintagel and Delabole.

*Sanadin* occurs in glassy, transparent, or translucent crystals imbedded in lava.

*Common felspar* is often pink, reddish, or grey. It is a common constituent of granite. It occurs in great masses of a pale pink colour in a quarry near Roche and in the cliffs of Tremearne, both in Cornwall. Fine grey crystals are also imbedded in the granite of Tol-pedn-penwith, near Penzance ; other varieties of felspar have been named *moonstone*, *murchisonite*, *erythrite*, *amazon stone*, etc.

The localities of common felspar are innumerable. Fine specimens may be obtained from almost every mountainous country in the world.

**32. Albite** [Soda Felspar].—*Anorthic*.  $H = 6$  ;  $G = 2.6$  ; the same as orthoclase ; crystals like figs. 106, 148 ; usually white and transparent, but sometimes colourless and transparent, or variously tinted ; two perfect cleavages forming angles of  $93^{\circ} 36'$  and  $86^{\circ} 24'$

*Comp.*—Anhydrous silicate of alumina and soda, with excess of silica ; scarcely soluble in acids.

*B. etc.*—Fusible at about 4, tinging the flame yellow.

*Loc. and Var.*—*Cleavelandite* is a lamellar white albite.

*Periclinc* occurs in white opaque crystals, which are often short and broad. Albite is less common than orthoclase, but pure specimens occur at Arendal, Norway, in Dauphine, at St. Gothard, and in many other places on the continent of Europe, as well as in North America. It is a constituent of many porphyritic greenstones, and has been found by Professor Haughton in the granites of Cornwall and Ireland.

**33. Oligoclase.**—*Anorthic*. H and G same as orthoclase and albite; often white and translucent to opaque. Crystals like those of albite, but the two cleavages forming angles of  $93^{\circ} 50'$  and  $86^{\circ} 10'$ . Crystals somewhat rare.

*Comp.*—Anhydrous silicate of alumina and soda, with a *small* excess of silica; very slowly and partially soluble in acids.

*B. etc.*—Fusible at about 3; tinges the flame yellow.

*Loc.*—White oligoclase occurs in the porphyries of the Hartz and Ural Mountains, and green in the Morea. A beautiful variety, called *avanturine felspar* or *sunstone*, occurs in Norway, Ceylon, and other places.

**34. Labradorite.**—*Anorthic*.  $H = 6$ ;  $G = 2.7$ , or nearly the same as the other felspars. Crystals rare and indistinct; often exhibiting a beautiful play of colours as viewed in different directions; cleavages like albite and oligoclase, but forming angles of  $93^{\circ} 20'$  and  $86^{\circ} 40'$ .

*Comp.*—Anhydrous silicate of alumina and lime, having a very complex formula. Slowly decomposed by H Cl, leaving gelatinous silica.

*B. etc.*—Fusible at or below 3, tinging the flame reddish yellow or brick red.

*Loc.*—Labradorite is a constituent of many greenstone and other eruptive rocks. It occurs abundantly at St. Paul's Island, Labrador.

**35. Amorphous Felspars.**—These are mineral substances, having no regular structure or definite form, but closely resembling in chemical composition the true felspars. They are often important, as they enter largely into the composition of certain volcanic rocks.



*Obsidian* occurs in globular masses or grains. It has a perfect conchoidal fracture, is very brittle, and of glassy appearance. It is usually black, brown, or dark green, sometimes striped or spotted, and readily fusible. It is abundant in the ancient volcanic rocks of Mexico, and was formerly much used by the Mexicans, who fashioned it into mirrors, knives, and arrow heads.

*Pumice* is a cellular and porous substance of very different appearance, but not greatly different in chemical composition to that of obsidian. It is usually grey, or of light colours, and although the powder has a specific gravity of 2·2, yet in masses it floats upon the surface of water. It occurs in the same localities as obsidian, and especially at the Island of Lipari, in the Mediterranean, where it forms a hill of near 1000 feet high.

*Pearlstone* occurs in roundish globules or concretions imbedded in a cellular or vesicular base. It is generally reddish, yellow, grey, or light brown, and melts to a white fungus-like mass. It occurs in great masses in Hungary, Siberia, and Mexico, as well as in the Isles of Arran and Shetland.

*Pitchstone* is compact, slaty, or scaly, with a conchoidal or splintery fracture. It often is scarcely to be distinguished from obsidian, but the lustre is usually duller. Colour grey, green, brown, or black. It forms great masses in the Isle of Arran, on the west coast of Scotland, near Newry in Ireland, and in many foreign localities. Readily fusible to a porous mass or grey enamel.

#### b. LEUCITE AND NEPHELINE GROUPS.

**36. Leucite.**—*Cubical*. H. 5·5—6; G 2·4—2·5. Lustre vitreous to resinous; crystals always in the form of fig. 42. Cleavage imperfect, parallel to the face. Colourless and transparent, but sometimes greyish, yellowish, or reddish.

*Comp.*—Anhydrous silicate of alumina and potash, without excess of silica. Soluble slowly, but completely, in H Cl.

*B. etc.*—Infusible; with borax melts readily to a clear glass, with Co turns blue.

*Loc.*—It is a somewhat common constituent of volcanic rocks, being abundant in the lavas of Vesuvius and the tufas near Rome. Large crystals often enclose small portions of lava, showing the later formation of the lava. In this mineral, Klaproth first discovered potash as a constituent of the mineral kingdom.

**37. Nepheline** [Elaolite].—*Hexagonal*.  $H = 5.5$  to  $6$ ;  $G = 2.5$  to  $2.6$ . Lustre vitreous; sometimes colourless and transparent, but often greenish, reddish, brownish, and translucent to opaque. Crystals small and not common. No very distinct cleavages.

*Comp.*—Anhydrous silicate of alumina, with occasionally a small proportion of lime, soda, and potash, without excess of silica. Dissolves in strong  $H\ Cl$ , leaving a small proportion of gelatinous silica.

*B. etc.*—Fusible with more or less difficulty to a clear glass; becomes blue when treated with Co.

*Loc.*—It occurs somewhat abundantly in the lavas of Monte Somma, around Vesuvius, and in many other volcanic districts.

**38. Prehnite.**—*Rhombic*.  $H = 6$  to  $7$ ;  $G = 2.5$  to  $2.6$ . Lustre vitreous or pearly. Crystals mostly indistinct; usually occurs in radiated or globular masses of various shades of green. Rather perfect cleavage parallel to  $OP$ .

*Comp.*—Hydrated silicate of alumina and lime ( $Al\ Ca$ )  $Si\ O_2 + H_2\ O$ . Soluble in concentrated  $H\ Cl$ , more readily if previously strongly heated.

*B. etc.*—Melts easily and with much intumescence to a porous enamel, giving off water in the closed tube.

*Loc.*—Fine crystals occur in Dauphiné, at Bourg d'Oisans, in the Tyrol, and in many parts of the Alps, Pyrenees, and Hartz Mountains, and in Norway, generally in cavities or fissures in granite or greenstone rocks. It occurs also in trap rocks in many parts of Scotland.

## c. HORNBLLENDE GROUP.

The hornblende group have a H little differing from 5.5, or somewhat softer than the felspars; G mostly above 3, or heavier than the felspars, and usually *one* perfect cleavage. They are mostly fusible with considerable readiness. Often there is a tendency to decomposition, and to fibrous or radiated forms. As the felspars are frequently yellow, pink, or red, so the hornblendes are very commonly some shade of green. There are, however, marked exceptions to each of these generalisations.

**39. Amphibole** [Hornblende, Actinolite, etc.]. — *Oblique.* H = 5.5; G = 3.2 to 4. Good crystals, not very common. Radiated and fibrous forms very common; lustre vitreous.

*Comp.*—A complex and variable anhydrous silicate of lime, magnesia, iron, and alumina. Scarcely acted upon by H Cl or H NO<sub>3</sub>.

*B. etc.*—Mostly fusible, the darker varieties most readily, and strongly magnetic after fusion.

*Loc. and Var.*—Hornblende is frequently very dark green and easily fusible, and contains a considerable proportion of iron, G 3.3 to 4. Fine crystals occur in the Ural, at Arendal in Norway, and other places, while massive hornblende enters largely into the composition of greenstone rocks. It is usually very liable to decomposition.

*Noble* hornblende is of a pale green colour, and of brilliant lustre.

*Actinolite* is of a lighter green than hornblende, more brittle and lustrous. It often forms fibrous or columnar masses. Fine specimens have been obtained from the Tyrol, Sweden, and many foreign localities, and from Cuddan Point in the Mount's Bay, Cornwall. It is a silicate of magnesia, iron, and lime, with little alumina.

*Asbestos* is nearly the same mineral, but the fibres are

finer and flexible, and often quite white. *Amianthus* is the same, but in extremely fine fibres.

*Asbestiform actinolite* is between asbestos and actinolite. All these occur in the Lizard Promontory, Cornwall, as well as in many other places.

*Tremolite* is very pale green or white, and seldom very glossy. It is a silicate of magnesia and lime, with little alumina or iron. Fine specimens occur in similar situations to those of actinolite and asbestos:

*Mountain wood, mountain paper, mountain cork, etc.*, are varieties of tremolite or asbestos often found associated with them.

**40. Pyroxene** [Augite, Sahlite, Diopside, etc.]—*Oblique*.  $H = 5.6$ ;  $G = 3.4$  to  $3.5$ . Lustre vitreous; crystals like figs. 103, 145. Radiated and fibrous forms common, but not so much so as in amphibole.

*Comp.*—A complex and very variable anhydrous silicate of lime, magnesia, and iron, with occasionally alumina. Scarcely acted upon by acids.

*B. etc.*—Mostly somewhat more readily fusible than the varieties of amphibole.

*Loc. and Var.*—*Augite* is leek-green to blackish-green, or sometimes quite black, or very dark brown. It is occasionally translucent, but usually nearly or quite opaque. Many of the crystals are maced, rough, and seem as if partly fused.

This is the most common form of the mineral, and it is in this form a frequent and large constituent of many rocks, such as basalt, dolerite, etc. It is often found in blocks or loose sand thrown out from volcanoes. It readily fuses to a magnetic globule.

*Diopside* is light green or greenish white, and nearly or quite transparent. It occurs in beautiful crystals with red garnets in the Alps of Piedmont and the Tyrol, and other parts of the chain, as well as in many other places.

*Sahlite* or *Malacolite* is green, yellow, brown, or red. It is seldom crystallized; but fine crystals, which have

been called *fassaite*, occur in various parts of Piedmont, at Arendal in Norway, etc.

*Diallage*, *bronzite*, *hypersthene*, and *smaragdite*, are sometimes described as varieties of pyroxene. Amphibole and pyroxene are very closely related species, if, indeed, they should not rather be viewed as one.

Dana remarks that "it is impossible to distinguish them by blowpipe characters alone." The range of chemical composition is so great as to render a chemical division in the highest degree artificial. Crystals of amphibole and pyroxene differ strikingly in habit and in modifications, but it is quite possible to refer all these modifications to the same system of axes. Twins or macles have been found composed part of amphibole and part of pyroxene. Hornblende, however, frequently occurs in rocks containing quartz or free silica, together with orthoclase or albite; while pyroxene occurs in rocks containing little or no free silica, and with such minerals as labradorite, olivine, and leucite.

#### d. GARNET GROUP.

The garnets have usually an H above 6 (from 6 to 7), or are somewhat harder than the feldspars, with a specific gravity of from 3 to 4.5, or considerably heavier than feldspars. They are anhydrous, and fusible, but not very easily so, and scarcely at all soluble in acids.

**41. Garnet.**—*Cubical*.  $H = 7$ ;  $G \ 3.5 = 4.3$ . Of all degrees of transparency or opacity and all colours. Scarcely ever any distinct cleavage; crystals like figs. 40, 42, 61.

*Comp.*—A very complex and variable silicate of many bases. Always nearly or quite insoluble in acids.

*B. etc.*—Generally fuses to a bead, which is strongly magnetic when much iron is present.

*Loc and Var.*—*a. Almandine* or *noble garnet* is red or reddish-brown, with a tinge of violet, very brilliant in colour, and transparent. It is chiefly an iron-alumina

garnet. The finest specimens come from Ceylon, but inferior specimens of a large size from Arendal in Norway.

*b. Grossularia* is pale-green and transparent or occasionally white. It is a lime-alumina garnet. It occurs in Siberia and Norway.

*c. Cinnamon stone* or *essonite* is hyacinth-red to orange, or honey yellow, and transparent. When polished it is often called hyacinth. It occurs in abundance in Ceylon.

*d. Lime garnet* is usually red or brown, more or less pure, and having always some iron present. It occurs in abundance in Piedmont and in ejected blocks of stone from Vesuvius.

*e. Magnesia garnet* is opaque and quite black.  $G = 3.157$ . It fuses easily and glows with a bright light. It occurs at Arendal in Norway. Besides magnesia and alumina, it often contains iron and manganese.

*f. Melanite* is black and opaque, and slightly magnetic. It contains alumina, lime, and iron.

*g. Colophonite* is yellowish-brown to black, with strong resinous lustre. It occurs with magnetic iron ore at Arendal in Norway.

*h. Uwarowite* or *chrome garnet* is bright green and infusible; it contains a large proportion of chromium and iron.

**42. Idocrase** [Vesuvian].—*Pyramidal*.  $H = 6.5$ ;  $G = 3.4$ ; crystals somewhat like fig. 83.

*Comp.*—Much the same as many garnets, being an anhydrous silicate of alumina, lime, and iron; differs from garnet only in crystalline form. Partially soluble in  $HCl$ .

*B. etc.*—Fuses easily with intumescence to a yellowish-green or brown glass.

*Loc.*—It occurs in fine crystals at Mount Vesuvius, at Mussa-alpe in Piedmont, and in many other places.

**43. Epidote.**—*Oblique*.  $H = 6-7$ ;  $G = 3.2-3.5$ . Lustre vitreous to adamantine; green, yellow, or grey, sometimes red or black; transparent to opaque. Crystals somewhat like fig. 103.

*Comp.*—Anhydrous silicate of alumina and lime, with sometimes iron; or scarcely different from garnet except in form. Not acted upon by acids unless previously ignited or fused.

*B. etc.*—Fusible; melts to a coloured glass or slag, which is often magnetic.

*Loc.*—Very fine crystals occur in the magnetic iron ore of Arendal in Norway, and in many other continental localities. Epidote has also been found in the syenites, traps, and clay-slates of Scotland, the Hebrides, and Shetland Isles, especially in Mull, Skye, and Arran.

**44. Axinite.**—*Anorthic.*  $H = 6.5-7$ ;  $G = 3-3.3$ . Lustre vitreous. Colours mostly brown, with a tinge of blue when viewed in some directions; transparent or translucent. Crystals sometimes like fig. 107, but usually very irregular in form. Some of the planes often striated or rough.

*Comp.*—Anhydrous silicate of alumina, lime, and iron, with small proportions of boracic acid and manganese.

*B. etc.*—Fuses easily to a dark-coloured glass, which is reddish or brown in the reducing flame, but bluish in the oxidising. Not acted upon by acids until after strong heating.

*Loc.*—Not very abundant; but forms considerable rock-masses at Arendal, Norway, Nordmark in Sweden, Bourg D'Oisans in Dauphiné, and Botallack Cliffs, Cornwall. The finest crystals are found in the last two localities. Axinite very well illustrates that peculiar property of some minerals, called *trichroism*, being sometimes cinnamon-brown when viewed in one direction, dark violet-blue in a second, and pale olive-green in a third.

#### e. TOPAZ GROUP.

These have generally a hardness of about 7, and a specific gravity varying from 2.6 to 4.6. They are anhydrous, infusible or nearly so, and not acted upon by acids.

**45. Topaz.**—*Rhombic*.  $H = 8$  ;  $G = 3.5$ . Lustre vitreous. Transparent to translucent; sometimes colourless, but usually yellow or brown, sometimes pale blue. Crystals mostly striated vertically; cleavage perfect, parallel to OP.

*Comp.*—Anhydrous silicate of alumina with a small proportion of fluorine.

*B. etc.*—Fusible, but not very readily, to a blistered glass. Not acted upon by acids.

*Loc.*—The finest topazes are brought from Saxony and Mexico. A few fine crystals have been found in joints of the granite rocks at St. Michael's Mount and other places in Cornwall. These latter are nearly or quite colourless, or with a pale bluish tinge.

False topaz, which often much resembles the real stone in colour and lustre, may be easily distinguished from it by its inferior hardness and the absence of a basal cleavage. Prisms of false topaz are also striated *horizontally* instead of *vertically*.

**46. Andalusite.**—*Rhombic*.  $H = 7-7.5$  ;  $G = 3.1-3.3$ . Lustre vitreous. Always grey, green, reddish, or brownish, but rarely with any intensity of colour. Seldom transparent; usually translucent or opaque. Crystals sometimes like fig. 87.

*Comp.*—Anhydrous silicate of alumina.

*B. etc.*—Infusible, with Co. turns blue; not affected by acids.

*Loc. and Var.*—*Andalusite* occurs mostly in square prisms imbedded in mica-slate. It was first found in Andalusia, but has since been found in many other localities. *Chiastolite* is a much softer variety, which occurs in curious compound prisms imbedded in clay-slate. It often appears as four crystals, separated by a black cross of the slate. It is found in Brittany, and at St. Jago di Compostella in Spain, where it is cut into ornaments and sold to the pilgrims. It has also occurred in Argyleshire, on Skiddaw in Cumberland, and in Wicklow, Ireland.



**47. Beryl** [Emerald, etc.]. — *Hexagonal*.  $H = 7.5$ ;  $G = 2.6-2.8$ . Lustre vitreous. Sometimes white and opaque, but mostly green; of more or less purity, and translucent to transparent. Crystals like figs. 111, 113. Generally deeply striated vertically; sometimes a tolerably perfect basal cleavage.

*Comp.*—Anhydrous silicate of alumina and berylla (glucina).

*B. etc.*—Fusible, but only with difficulty. Not affected by acids.

*Loc. and Var.*—*Emerald* is the clear and brilliant green variety, and when pure is one of the most valuable of precious stones. The finest crystals are obtained from Peru.

*Beryl* or *Aquamarine* is the less brilliant or finely coloured variety. Very large crystals are occasionally found. One crystal from Ackworth in New Hampshire, U.S.A., measured 4 feet long,  $5\frac{1}{2}$  inches across the faces, and weighed 238 lbs. Another was 4 feet 3 inches long, 2 feet 8 inches wide, and 1 foot 10 inches thick.

**48. Tourmaline** [Schorl, etc.]. — *Hexagonal*.  $H = 7-7.5$ ;  $G = 3-3.3$ . Lustre vitreous; occasionally colourless and transparent, but usually coloured grey, yellow, green, red, blue, or brown, and translucent. The most common variety (schorl) is black and opaque. Crystals like figs. 121-123, the vertical planes deeply striated. Very brittle.

*Comp.*—Anhydrous silicate of alumina, iron, and many other bases, with a small proportion of boron.

*B. etc.*—Generally fusible, the dark varieties forming a dark magnetic slag. Not acted upon by  $HCl$  or  $HNO_3$ ; scarcely by  $H_2SO_4$ .

*Loc. and Var.*—*Noble tourmaline* is beautifully brilliant and transparent. It occurs in Ceylon, Siberia, and Brazil.

*Rubellite* is mostly red; it occurs in Ava.

*Indicolite* is a dark blue variety, occurring at Utoe.

*Schorl* is the common black opaque variety which

occurs in almost all tin-mines, and is often associated with granite rocks. With quartz it forms the beautiful rock known as schorl rock or schorlyte. Very fine crystals of schorl have been found at Bovey Tracey in Devon, and at Botallack in Cornwall. Schorl is called cockle by the Cornish miners.

**49. Olivine** [Chrysolite, Peridot].—*Rhombic*.  $H = 6.5 - 7$ ;  $G = 3.3 - 3.5$ . Lustre vitreous. Usually green or greenish-yellow, and transparent to translucent; sometimes yellow or brown. Crystals rather rare. Usually occurs in loose grains, or imbedded in basalt or lava.

*Comp.*—Anhydrous silicate of magnesia and iron.

*B. etc.*—Mostly infusible, except the dark coloured varieties, which fuse readily to a black magnetic glass. Easily decomposed by  $H_2SO_4$ , less readily by  $HCl$ , the silica gelatinizing.

*Loc. and Var.*—*Chrysolite* is the fine golden-green variety, which is sometimes cut as a precious stone.

*Olivine* is darker and less brilliant. It occurs in the lavas and ejected blocks of Vesuvius. It is seldom crystallized there; but fine crystals are obtained from some of the extinct volcanoes of the Rhine. It is abundant in many basalts, occurring in small rounded grains.

### f.—MICA GROUP.

The micas usually occur in thin flexible plates or scales, with perfect basal cleavage. They are generally anhydrous, and not easily acted upon by acids; mostly fusible, hardness not more than 2.5 or 3;  $G$  about 3. Thin plates are *flexible* and *elastic*.

**50. Muscovite** [Potash Mica].—*Oblique?*  $H = 2 - 2.5$ ;  $G = 2.8 - 3.1$ . Generally transparent, and mostly brown or yellowish. Lustre metallic or sub-metallic, or occasionally pearly. Crystals rare, but often occurs in hexagonal scales.

*Comp.*—Anhydrous silicate of alumina, potash, and other bases.

*B. etc.*—Fusible without much difficulty.

*Loc.*—It is a common constituent of granite and mica-schist. Fine large plates occur in Siberia, where it is often used instead of glass, and large masses in St. Dennis and other parts of Cornwall. Muscovite may be distinguished from talc, brucite, and selenite by its extreme elasticity.

**51. Lepidolite** [Lithia-Mica]. — *Oblique*.  $H = 2$ ;  $G = 2$ ; lustre vitreous or pearly. White or peach blossom, red; transparent to translucent. Crystals rare, but often occurs in hexagonal plates.

*Comp.*—Anhydrous silicate of alumina and lithia, with other bases.

*B. etc.*—Readily fusible, tinging the flame clear red, especially if moistened with  $HCl$  or  $H_2SO_4$ .

*Loc.*—It occurs in beautiful pearly scales at St. Michael's Mount and other localities in Cornwall. A fine pink-coloured mass, composed of minute pearly scales, is quarried in Moravia. Lepidolite occurs in many of the Cornish and Irish granites.

**52. Lepidomelane** [Iron-Lithia-Mica].  $H = 3$ ;  $G = 3$ ; lustre vitreous to metallic or adamantine. Usually black, with green streak. Crystals rare; hexagonal scales not uncommon.

*Comp.*—Anhydrous silicate of alumina, lithia, iron, and other bases.

*B. etc.*—Fuses to a dark magnetic bead. Soluble in  $HCl$  or  $HNO_3$ .

*Loc.*—Fine hexagonal scales have occurred at Carn Bosavern, near the Land's End, Cornwall.

**53. Biotite** [Magnesia-Mica]. — *Hexagonal?*  $H = 2.5$  to 3;  $G = 2.8$  to 2.9; lustre metallic to pearly. Usually dark green, brown, or black. Crystals very rare.

*Comp.*—Anhydrous silicate of alumina and magnesia, with often iron and potash.

*B. etc.*—Like muscovite.

*Loc.*—Fine dark-coloured plates occur in the blocks ejected from Mount Vesuvius, and in other localities.

**54. Chlorite [Peach].—Hexagonal.** H. = 1 to 1·5; G. = 2·9. Usually green or bluish; translucent when in scales, opaque when earthy. Crystals very rare.

*Comp.*—Hydrated silicate of alumina, magnesia, and iron.

*B. etc.*—Difficultly fusible; soluble in concentrated sulphuric acid.

*Loc.*—It is very widely distributed in nature, entering largely into the composition of extensive beds of chlorite slate in the Alps, Scandinavia, and many parts of Scotland. It is also common in veins or lodes of ore, especially those of tin ore in Cornwall.

#### g. ZEOLITE GROUP.

The zeolites are hydrous silicates of alumina, together with some alkali or alkaline earth. They occur frequently in the cavities of ancient volcanic rocks or of modern lavas. The hardness varies considerably, some being so soft as to be scratched readily with the finger nail, others so hard as to be with difficulty scratched with a knife. All are fusible, some very readily, and all are decomposed by H Cl, the silica remaining as a slimy powder or a gelatinous mass.

**55. Alalcite [Alalcime].—Cubical.** H = 5·5; G = 2·2; lustre vitreous. Sometimes colourless and transparent, but usually greyish, greenish, yellowish, or reddish; translucent to opaque. Crystals like figs. 42, 59. No distinct cleavage.

*Comp.*—Hydrous silicate of alumina and soda.

*B. etc.*—Melts quietly, and rather easily to a clear glass, tinging the flame strongly yellow. In closed tube becomes (if not already) milk-white, and gives off much water. Completely decomposed by H Cl.

*Loc.*—Fine large crystals occur in the southern Tyrol, and near Dumbarton in Scotland. Smaller crystals are found in the Cyclopean Islands near Sicily, and in several parts of Scotland, Ireland, and the Hebrides, mostly in cavities or fissures of basaltic and trachytic rocks.

**56. Natrolite** [Mesotype].—*Rhombic*.  $H = 5$  to  $5.5$ ;  $G = 2.2$ ; lustre vitreous. Colourless, white, or tinted greyish, reddish-yellowish, translucent to opaque. Crystals somewhat fibrous; commonly occurs in masses of indistinct acicular crystals. Perfect cleavage, parallel to the faces of the prism.

*Comp.*—Hydrous silicate of alumina and soda.

*B. etc.*—Like analcite.

*Loc.*—Occurs in basaltic and trachytic rocks in veins or cavities. Fine crystals have been obtained in Auvergne, Central France. It is common in the rocks of Mull, Canna, and other parts of Scotland, and at the Giant's Causeway, Ireland.

**57. Stilbite**.—*Rhombic*.  $H = 3.5$  to  $4$ ;  $G = 2.2$ ; lustre usually pearly, but some crystals vitreous. Colourless, white, or variously tinged, occasionally brick-red or brown; translucent to opaque. Crystals like fig. 92, with a perfect cleavage, parallel to the prism, but more frequently in indistinct groups.

*Comp.*—Hydrous silicate of alumina and lime.

*B. etc.*—In closed tube gives off much water. Fusible, but not very readily, after much intumescence; tinges the flame yellow, but not so strongly as analcite. Decomposed by  $HCl$ , leaving a slimy siliceous powder.

*Loc.*—It occurs with other zeolites in ancient porphyritic rocks, but is rare in basalt. Fine crystals are obtained from Iceland, Faroe, and the Vendayah mountains in India. Flat four-sided prisms are found in Skye, brick-red crystals at Old Kilpatrick, and brown crystals at Kilmalcolm, all in Scotland. Unlike most other zeolites, it is frequently associated with granite, gneiss, and other plutonic rocks, as well as with beds of magnetite, and in metallic veins, as in the Hartz Mountains, and at Arendal in Norway.

**58. Chabazite** [Gmelinite].—*Hexagonal*.  $H = 4$ — $4.5$ ;  $G = 2$ — $2.2$ . Lustre vitreous; transparent to translucent; sometimes colourless, but usually greyish, yellowish, red-

dish, or flesh-red; often occurs in masses of small imperfect crystals.

*Comp.*—Hydrous silicate of alumina and lime.

*B. etc.*—Fusible to a finely porous enamel. In closed tube gives off much water; soluble, except the silica, in H Cl.

*Loc. and Var.*—It occurs in lava, basalt, and other ancient and modern volcanic rocks, also in syenite rocks and metallic veins. Fine crystals occur in Faroe, Iceland, Giant's Causeway, and many other localities. *Chabazite*, *levyne*, *phacolite*, and *gmelinite*, are names of varieties differing somewhat in form.

#### h. SERPENTINE GROUP.

These are rather soft and light, and most of them feel somewhat slippery or greasy. They are simply silicates of magnesia or alumina without alkalis.

**59. Serpentine** [Ophiolite].—*Rhombic*.  $H = 3$  to  $4$ ;  $G = 2.6$ . Lustre resinous or dull; translucent to opaque. Colour, various shades of green, red, and brown, often veined or mottled. The purest specimens, pure oil green. Crystals extremely rare; mostly forms rock masses. It is either foliated, lamellar, fibrous, or massive.

*Comp.*—Hydrous silicate of magnesia.

*B. etc.*—Infusible, yields water in closed tube and turns black. Soluble in H Cl or  $H_2SO_4$ .

*Loc.*—Fine specimens occur in the Lizard Promontory, Cornwall, in Connemara, Ireland, in various parts of Scotland, and the Shetland Isles.

**60. Talc.**—*Hexagonal*.  $H = 1$  to  $1.5$ ;  $G = 2.6$  to  $2.8$ . Lustre pearly; usually white or pale green, sometimes yellowish; translucent to opaque. Crystals very rare; mostly in foliated masses, the thin foliæ being flexible, but not elastic. Feels greasy.

*Comp.*—Anhydrous silicate of magnesia.

*B. etc.*—In closed tube sometimes yields a *little* water. Infusible, but if strongly heated glows with a bright

**Right.** With Co turns pink or red. Insoluble in H Cl or  $\text{HNO}_3$ .

*Loc.*—Fine specimens occur at Greiner in Tyrol, Unst in the Shetland Isles, and occasionally in the Lizard Serpentine of Cornwall. Talc enters largely into the formation of the rock called talc slate, which sometimes extends over large districts. Talc is often confounded with mica, but it may be readily distinguished from mica by its infusibility and want of elasticity.

**61. Steatite** [Saponite, Soapstone].—*Amorphous.*  $\text{H} = 1$  to  $2.5$ ;  $\text{G} = 2.2$  to  $2.8$ ; lustre waxy or dull; translucent to opaque, white or almost all colours, often mottled or veined. Feels greasy.

*Comp.*—Hydrated silicate of magnesia, with some alumina.

*B. etc.*—In closed tube gives off water, and often darkens. On C generally fuses at about 4 to a vesicular glass or enamel. Some varieties are infusible. Partially soluble in hot  $\text{H}_2\text{SO}_4$ .

*Loc.*—It is often found in the Serpentine rocks of the Lizard and elsewhere, where it is, if soft, called soapstone; if hard, talc. It was formerly obtained in large quantities from Gue Grease in Cornwall, and used in the potteries. The harder kinds are of considerable value for cutting into gas burners, &c.

**62. Kaolin** [China Clay, Lithomarge, etc.].—*Amorphous.*  $\text{H} = 1$  to  $3$ ;  $\text{G} = 1.8$  to  $2.7$ . When pure, white, but frequently yellow, red, brown, or slaty blue; occurs in extensive beds or veins, and is rather a rock than a mineral. Unctuous and plastic when moist.

*Comp.*—Hydrous silicate of alumina.

*B. etc.*—In closed tube gives off water. On C the pure white varieties are very infusible, but glow brightly when strongly heated. With Co turns blue. Dark coloured varieties frequently fuse to a magnetic slag.

*Loc. and Var.*—*Kaolin* or *China clay* is the pure white variety used for making high-class pottery. It is abundant near St. Austell and St. Stephen's in Cornwall, at

Lee Moor, in Devonshire, and in many other localities in the two counties.

*Pipe clay* is white or greyish white, and feels very greasy.

*Potters' clay* is more easily fusible, and generally red, yellow, blue, or green, becoming yellow or red when burnt.

*Lithomarge* is a peculiar hard variety, of a greasy feel, which has occurred in Dolcoath, Carn Brea, and some other Cornish mines. Many other varieties have been named.

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## SECTION II.—ALUMINATES.

In these the alumina seems to perform the office of the silica in the silicates, combining with various bases to form aluminates.

**63. Spinel.**—*Cubical.*  $H = 8$ ;  $G = 3.4$  to  $3.8$ ; lustre vitreous; transparent to opaque, sometimes colourless, but usually coloured various shades of red, blue, or purple, or black. Crystals mostly macled, like fig. 132.

*Comp.*—Anhydrous aluminate of magnesia, with sometimes iron, chromium, zinc or manganese, and a *little* silica.

*B. etc.*—Infusible, and usually unchanged; with borax fuses to a clear bead, showing the colour due to the oxide of the heavy metal present. Insoluble in acids.

*Loc. and Var.*—*Spinel ruby* is red or violet. It occurs chiefly in loose grains in the sands of the rivers of Ceylon.

*Saphirine* is a blue variety occurring in Sweden.

*Balas ruby* is rose red. *Rubicelle* is orange red or yellow, and *almandine ruby* is violet.

*Pleonaste* is a very dark variety found in loose crystals in Ceylon, and imbedded in dolomite on Monte Somma, near Naples, at Arendal in Norway, and in other places.

*Chloro-spinel* is grass green; it occurs in talc-slate at Slatoust Ural. All the finely coloured varieties of spinel, when large enough, are highly prized as ornamental stones.



## DIVISION II.—METALLIC MINERALS.

(Contain a considerable proportion of the true or heavy metals, have often a metallic lustre, a streak frequently darker than the colour, which latter is often constant and characteristic; specific gravity often over 5; very many are opaque.)

CLASS I.—MINERALS CONTAINING METALS THAT  
ARE BRITTLE, AND FUSIBLE ONLY WITH DIFFI-  
CULTY.

(*Manganese, Tungsten, Uranium, &c.*)

## a. MANGANESE GROUP.

ALL the minerals in this group form a green mass when fused on platinum foil with soda. With borax in O F the bead is amethystine, and in R F becomes colourless.

**64. Pyrolusite** [Black Oxide of Manganese.]—*Rhombic*.  $H = 2-2.5$ ;  $G = 4.7-5.0$ . Opaque; lustre metallic, sub-metallic, or silky; colour black or bluish-black; streak black. Crystals somewhat rare. Occurs usually in beautiful radiated masses, or occasionally earthy.

*Comp.*—Anhydrous oxide of manganese,  $MnO_2$ .

*B. etc.*—Infusible, but turns brown; yields chlorine if warmed with H Cl. Usually so friable as to soil the fingers while handling.

*Loc.*—Abundant in the manganese mines of Thuringia and Moravia, and is by no means rare at Lifton and Upton Pyne in Devon. Much used in the preparation of chlorine for bleaching purposes, and in other chemical manufactures; also used in the manufacture of glass and of oxygen gas.

**65. Psilomelane.**—*Amorphous*.  $H = 5.5-6$ ;  $G = 4-4.4$ . Opaque; lustre metallic, sub-metallic, or silky; colour black or bluish-black; streak dark-brown. Occurs usually in botryoidal or reniform masses.

*Comp.*—Hydrated peroxide of manganese, of somewhat variable composition, often contains small proportions of other bases.

*B. etc.*—Yields water in closed tube, otherwise like pyrolusite.

*Loc.*—Found frequently associated with pyrolusite.

**66. Manganite** [Grey oxide of manganese].—*Rhombic*.  $H = 3.5-4$ ;  $G = 4.2-4.4$ . Opaque; Lustre metallic; colour steel grey; streak black or dark brown; crystals mostly prisms, often deeply striated vertically; the prisms often grouped in bundles; one perfect cleavage parallel to the brachydiagonal.

*Comp.*—Hydrated sesqui-oxide of manganese,  $Mn_2O_3$ ,  $H_2O$ .

*B. etc.*—Like pyrolusite.

*Loc.*—It occurs associated with pyrolusite and manganite in most of its localities. Fine crystals occur in veins in porphyry, with calcite and barytes at Ihlefeld in the Hartz. It is used for the same purposes as pyrolusite, but is neither so common nor so valuable.

**67. Wad.**—*Amorphous*.  $H = 0-3$ ;  $G = 2-3.7$ . Opaque; metallic lustre or dull; black or brown; often occurs in botryoidal; reniform, or stalactitic masses; occasionally as a soft powder; soils the fingers; streak dark brown and shining.

*Comp.*—Hydrated oxide of manganese, but often containing small proportions of other bases; composition uncertain.

*B. etc.*—Like Pyrolusite.

*Loc.*—Frequently associated with the other ores of manganese. The ochrey variety was formerly found in considerable abundance at Upton Pyne in Devonshire.

**68. Diallogite.**—*Hexagonal*.  $H = 3.5-4.5$ ;  $G = 3.5$ . Translucent to opaque. Lustre vitreous or pearly; usually pink or rose-coloured; streak white or very light; crystals very rare; cleavage perfect, parallel to the rhombohedral faces; more often occurs in botryoidal masses of radiated structure.

*Comp.*—Anhydrous carbonate of manganese,  $\text{Mn CO}_3$ .

*B. etc.*—Infusible. Often decrepitates and turns greenish grey or black; slowly soluble in cold  $\text{H Cl}$ ; rapidly and with effervescence in warm.

*Loc.*—It occurs in veins in gneiss and porphyry, with ores of silver, lead, copper, and zinc at Freiberg, Schemnitz, Kapnik, Nagyag, in Germany and Hungary, as well as in other places. A few specimens have occurred at Botallack Mine in Cornwall, and at Bovey Tracy in Devon.

**69. Rhodonite.** — *Oblique.*  $\text{H} = 5.5 - 7$ ;  $\text{G} = 3$ . Transparent to translucent or opaque; lustre vitreous, pearly, or dull; usually pink or rose-coloured, occasionally reddish-brown. Crystals very rare, one perfect cleavage. Mostly occurs in granular or compact masses.

*Comp.*—Anhydrous silicate of manganese,  $\text{Mn SiO}_3$ , with often small quantities of lime, iron, or magnesia.

*B. etc.*—Fusible in RF to a reddish glass, in OF to a black metallic globule. Not affected by acids.

*Loc.*—In the Hartz Mountains associated with other ores of manganese, and in many other localities on the continent. It was found formerly in a quarry near Callington in Cornwall, and at Upton Pyne in Devon.

#### b. TUNGSTEN GROUP.

**70. Wolfram** [Tungstate of Iron]. — *Rhombic.*  $\text{H} = 5 - 5.5$ ;  $\text{G} = 7.2 - 7.5$ ; nearly or quite opaque; colour dark brown or nearly black; streak dark brown; lustre metallic or sub-metallic, or resinous; crystals sometimes like fig. 144, with one very perfect cleavage parallel to the clinodiagonal (*a*). Macles common; vertical faces deeply striated.

*Comp.*—Anhydrous tungstate of iron,  $\text{Fe WO}_4$ , often contains a small proportion of manganese.

*B. etc.*—Infusible, or sometimes fusible to a magnetic globule. Decrepitates strongly and flies to pieces in thin flakes; with micro in OF yellowish-green, in RF a dark red bead, fused with soda or platinum foil usually gives a

green mass, showing presence of manganese. Soluble in warm HCl, leaving a bright yellow residue of tungstic anhydride.

*Loc.*—Occurs largely with tin ore in several of the Cornish mines, especially at East Pool near Redruth, and Drake-walls near Calstock. The finest crystals are found at Altenberg, Geyen in Saxony, Zinnwald in Bohemia, and other continental localities. Crystals are rare in Cornwall although large masses are common. It is occasionally mistaken for tin ore, but may be easily known by its dark streak, perfect cleavage, and inferior hardness, as well as by its solubility in warm HCl.

### c. URANIUM GROUP.

71. Pitchblende [Pechurane].—*Amorphous*.  $H = 5.5$ ;  $G = 6.4-7$ . Opaque; black or dark-brown; streak the same. Metallic or sub-metallic lustre; sometimes botryoidal or reniform.

*Comp.*—Anhydrous proto-peroxide of uranium,  $UO$ ,  $U_2O_3$  or  $U_3O_4$ .

*B. etc.*—Infusible; with borax OF, a yellow bead RF a greenish bead. Insoluble in HCl, easily soluble in warm  $HNO_3$ , or in aqua regia.

*Loc.*—Annaberg, Schneeberg, and other places in Saxony; Příbram in Hungary, and other foreign localities. In Cornwall it has been found at Tincroft, Tol Carne, Providence, and some other mines, and more recently at Huel Edward, St. Just.

## CLASS II.—MINERALS CONTAINING METALS THAT ARE BRITTLE, EASILY FUSIBLE, AND VOLATILE.

(*Arsenic, Antimony, Bismuth, etc.*)

### a. ARSENIC GROUP.

Arsenic, and many other minerals in other groups which contain arsenic, when heated on charcoal, give off

a white smoke, and deposit a white incrustation on the cool part of the charcoal at some little distance from the assay piece operated upon. At the same time a peculiar odour, resembling that of garlic, is usually observed, and the blowpipe flame is tinged *blue*.

**72. Arsenic** [Native Arsenic].—*Hexagonal*.  $H = 3.5$ ;  $G = 6$ . Opaque; dark-grey; streak grey and shining; metallic lustre or dull; crystals very rare; cleavage perfect, parallel to OP.

*Comp.*—Metallic arsenic, As, more or less contaminated with other metals.

*B. etc.*—Volatilizes readily and completely without previously melting. Changes to a white powder if treated with  $HNO_3$ , the white powder ( $As_2O_3$ ) being soluble in HCl.

*Loc.*—In veins with ores of antimony, silver, and lead; at Andreasberg in the Hartz, Annaberg, Schneeberg in Saxony, and many other localities.

**73. Orpiment.**—*Rhombic*.  $H = 1.5-2$ ;  $G = 3.4-3.5$ ; translucent to opaque; colour and streak various shades of yellow; lustre resinous or pearly. Crystals rare; cleavage very perfect and striated vertically. Occurs usually in irregular foliated or granular masses or drusy coatings.

*Comp.*—Anhydrous arsenious sulphide,  $As_2S_3$ .

*B. etc.*—In closed tube furnishes a dark-yellow or red sublimate, if mixed with soda or black flux a dark metallic sublimate; in the open tube burns, giving off an odour of burning sulphur, and deposits a white sublimate of  $As_2O_3$ . Soluble in aqua regia.

*Loc.*—Tajowa in Hungary, Hall in Tyrol (in gypsum), and many other localities. It is largely produced artificially as a yellow pigment.

**74. Realgar.**—*Oblique*.  $H = 1.5-2$ ;  $G = 3.4-3.6$ ; translucent to opaque; colour and streak various shades of red or orange; lustre resinous; crystals rare; two rather perfect cleavages. Occurs usually in irregular masses.

*Comp.*—Anhydrous arsenic mono-sulphide,  $\text{AsS}$ .

*B. etc.*—Like orpiment.

*Loc.*—Fine crystals at Kapnik and Nagyag in Hungary, and small crystals on Vesuvius. Largely prepared artificially as a yellow pigment.

### b. ANTIMONY GROUP.

The minerals in this group are mostly soft and fusible; when heated on charcoal yield white incrustations of oxide on the cool part of the support, but as antimony oxide is less volatile than that of arsenic, the incrustation is nearer the assay. The garlic odour is wanting, unless the mineral contains some arsenic as an impurity, and the blowpipe flame is tinged *green*.

**75. Antimonite** [Stibnite, Grey Antimony Ore].—*Rhombic*.  $H = 2$ ;  $G = 4.5$ ; opaque; lustre metallic; colour steel or lead grey; streak dark-grey or black; crystals like fig. 237, but rare; some a good deal like fig. 83; cleavage parallel to the prismatic faces, perfect and often striated. Often occurs in fibrous masses which mark paper like graphite.

*Comp.*—Anhydrous antimonous sulphide,  $\text{Sb}_2\text{S}_3$ .

*B. etc.*—In closed tube a yellow sublimate. On charcoal fuses easily, colouring the flame green, volatilizes, and leaves a white coating on the charcoal support. Soluble in warm  $\text{HCl}$ , giving off sulphuretted hydrogen. Decomposed by nitric acid.

*Loc.*—Endellion, Cornwall, in fibrous masses, formerly. Some of the chief foreign localities are Brannsdorf in Saxony, Wolfsberg in the Hartz, and Příbram in Bohemia. It is the chief ore of antimony.

**76. Jamesonite.**—*Rhombic*.  $H = 2 - 2.5$ ;  $G = 5.5$ . Opaque; lustre metallic; steel-grey colour; streak dark lead-grey. Distinct crystals very rare. Generally occurs in fibrous masses, or bundles of acicular prisms compressed together. Cleavage perfect, transverse to the principal *axis* of the prisms.

*Comp.*—Anhydrous sulphide of lead and antimony,  $2 \text{Sb}_2 \text{S}_3 + 3 \text{Pb S}$ .

*B. etc.*—Decrepitates. In closed tube a yellow sublimate. On charcoal fuses easily and wholly volatilizes, except a small portion of slag; tinges the flame green, and deposits a yellow incrustation. Soluble in warm  $\text{H Cl}$ , except a white deposit of chloride of lead.

*Loc.*—Endellion, Cornwall, Estremadura in Spain, and other localities. Jamesonite often much resembles antimonite, but it may be readily distinguished by the perfect transverse cleavage, greater specific gravity, and residue of chloride of lead when dissolved in warm  $\text{H Cl}$ . Both jamesonite and antimonite may be easily distinguished from pyrolusite by their ready fusibility.

### c. BISMUTH GROUP.

Minerals containing bismuth are mostly soft, fusible, and heavy. They yield yellow or brown incrustations when heated on charcoal. They are soluble in  $\text{HNO}_3$ , forming a clear solution, which becomes white and opaque by the addition of a *large* quantity of water. They are easily reduced to metal when heated on charcoal; the metallic bead much resembles lead, but is somewhat brittle, falling to pieces if struck with a hammer.

**77. Bismuth** [Native Bismuth].—*Hexagonal*.  $\text{H} = 2 - 2.5$ ;  $\text{G} = 9.8$ . Opaque; lustre metallic; colour reddish-white; streak greyish. Crystals somewhat like fig. 114, but not common; perfect cleavage, parallel to R.

*Comp.*—Metallic bismuth, Bi, usually contains small proportions of some other metals.

*B. etc.*—Fuses readily, deposits a yellow-brown coating on charcoal. Soluble in  $\text{HNO}_3$ .

*Loc.*—Fine specimens have been obtained from Dolcoath Mine and St. Ives Consols, both in Cornwall. The finest specimens are obtained from Schneeberg, Annaberg, and other places in Saxony, and Joachimsthal in Bohemia.

**78. Bismuthinite** [Bismuthine].—*Rhombic*.  $H = 2-2.5$ ;  $G = 6.4-6.6$ . Opaque. Lustre metallic; colour and streak reddish or greyish-white; often iridescent. Crystals usually acicular, and deeply striated longitudinally; one perfect and one imperfect longitudinal cleavage. Sometimes massive or granular.

*Comp.*—Anhydrous sulphide of bismuth,  $Bi_2S_3$ .

*B. etc.*—In closed tube yields a sublimate of sulphur. On charcoal fuses readily, sputters, and deposits a yellow coating, leaving a grain of metallic bismuth. Soluble in  $HNO_3$ .

*Loc.*—The finest specimens have occurred in Saxony with native bismuth, but beautiful bunches of acicular crystals occur occasionally at East Pool and other mines near Redruth, and at Botallack Mine, St. Just, all in Cornwall.

**CLASS III.—MINERALS CONTAINING METALS THAT ARE MALLEABLE, BUT WHOSE OXIDES ARE NOT REDUCIBLE BY HEAT ALONE.**

(*Zinc, Tin, Lead, Iron, Cobalt, Nickel, Copper, etc.*)

**a. ZINC GROUP.**

These minerals are neither very hard nor very heavy, and have but rarely a metallic lustre or dark streak. All give, if heated on charcoal, a white incrustation in OF. This is yellow while hot, and becomes green on cooling if treated with Co.

**79. Calamine** [Smithsonite *Dana*].— $H = 5$ ;  $G = 4.5$ . Translucent to opaque. Lustre vitreous; colour white, grey, green, yellow, or brown; streak light. Crystals very rare. Occurs mostly in compact or cellular masses, or botryoidal, with conchoidal fracture, much resembling chalcedony.

*Comp.*—Anhydrous carbonate of zinc,  $ZnCO_3$ . Pure specimens contain about 52 per cent. of zinc.

*B. etc.*—Infusible. Soluble with effervescence in  $HCl$ .



*Loc.*—Fine specimens occur at Alston Moor in Cumberland, the Mendip Hills in Somersetshire, Matlock in Derbyshire, and in some foreign localities. Those varieties which resemble chalcedony may be readily distinguished from that substance by their inferior hardness, greater specific gravity, and solubility in HCl.

**80. Smithsonite** [Electric-Calamine, Galmei]. — *Rhombic*.  $H = 5$ ;  $G = 3.5$ . Translucent to opaque. Lustre, colour, streak, and general appearance much like calamine. Crystals very rare.

*Comp.*—Silicate and hydrate of zinc,  $Zn Si O_6 + Zn H_2 O_2$ .

*B. etc.*—Infusible, but becomes strongly electric when moderately heated; gives off moisture if heated in closed tube, does not effervesce with acids, but is slowly decomposed.

*Loc.*—Cumberland, Derbyshire, and Somersetshire, and many foreign localities; often associated with calamine, from which it may be readily distinguished by its lower specific gravity, and by not effervescing when treated with HCl.

**81. Blende** [Black Jack]. — *Cubic*.  $H = 3.5-4$ ;  $G = 3.9-4.2$ . Lustre resinous, or in very dark specimens sub-metallic; translucent to nearly opaque. Sometimes white, but usually yellow, red, brown, or sometimes black; streak white, or lighter than the colour. Crystals like figs. 38, 39, 40, 45, 51 to 57, 62, 64, 67, etc., with three distinct cleavages, the best being parallel to the faces  $d$ ; sometimes occurs in radiated masses.

*Comp.*—Anhydrous sulphide of zinc,  $Zn S$ , containing, when pure, 66.8 per cent. zinc.

*B. etc.*—Infusible, or only fusible in thin edges. Decepitates, and gives off a very little sulphur in closed tube. Decomposed slowly by HCl, giving off sulphuretted hydrogen.

*Loc.*—Fine specimens occur at West Chiverton and many other mines in Cornwall. Very pale yellow blende occurs at Huel Uny near Redruth, and black blende at

Huel Jane near Truro, and many other places. Green, yellow, brown, and black blendes occur in many parts of Germany and Hungary, as well as in the United States of America. Blende is now much used as an ore of zinc, but is not so valuable as calamine, although the purest varieties contain 66 per cent. of zinc, while the purest calamines only contain 52 per cent. This is owing to the greater difficulty there is in smelting the blende, which indeed has only within a few years been smelted at all. Blende is sometimes mistaken for wolfram, but it may be readily distinguished by its softness, lower specific gravity, and light-coloured streak.

#### b. TIN GROUP.

**82. Cassiterite [Tinstone].—Pyramidal.**  $H=6$  to  $7$ ;  $G=6.8$  to  $7$ ; translucent to opaque. Lustre resinous or adamantine. In dark-coloured varieties almost metallic. Colours varying from very pale greyish-yellow to red, brown, and black. Streak white, or very light-coloured. Crystals like figs. 81, 82, 83, 136, 137, and many other forms, often distorted, and many of the planes striated. Macles common. No distinct cleavage. Occurs also frequently disseminated in minute particles in granite or slaty rocks, or in pebbles in valley gravels.

*Comp.*—Anhydrous peroxide of tin,  $\text{Sn O}_2$ . Very often there is a small proportion of iron or manganese present. Pure specimens contain 79 per cent. of tin.

*B. etc.*—Infusible in  $\text{OF}$ ; in  $\text{RF}$  is reduced with some difficulty to metal. By the addition of soda and borax, or of a little cyanide of potassium, this reduction is quite easy. Insoluble in acids.

*Loc. and Var.*—It is very abundant in Cornwall, where the tin stream works and mines have been worked for above two thousand years. It occurs also in Devonshire, but not so abundantly. Tin ore has also been found in Saxony, Bohemia, Spain, Banca, Australia, and Mexico. The Cornish crystals are usually small, but very brilliant. Spanish and German crystals are often dull,

but large, and of a brown colour. The chief varieties of tin ore are the following :—

1. *Diamond Tin*.—A miner's term for crystals when of a considerable size.

2. *Sparable Tin*.—A term for the small acute pyramids, like fig. 81.

3. *Rosin Tin*.—Reddish or yellowish, transparent or semi-transparent varieties are so called.

4. *Wood Tin* is a fibrous variety of various shades of brown or yellow, arranged in concentric bands.

5. *Toad's-eye Tin* is a variety of wood tin occurring in small spherical masses, embedded in a mass of darker or lighter colour.

6. *Stream Tin* is found in pebbles or water-worn masses in the lower layers of some of the river gravels in Cornwall and Devonshire. It was formerly very abundant, but is now somewhat scarce. It is often of the kind called wood tin. It is also found in most of the foreign localities of tin ore.

7. *Mine Tin* is the general name for that which occurs disseminated through, or in veins traversing, granite and slaty rocks.

### C. LEAD GROUP.

Lead ores are mostly not very hard, being easily scratched with a knife; but they are always rather heavy, the specific gravity varying from about 6 to 7.5. Only one, galena, has metallic lustre. All of them are easily reduced when heated in R F on charcoal, with or without soda, and all deposit a yellowish incrustation of oxide near the assay. All are dissolved or decomposed by  $\text{HNO}_3$ , and the clear solution yields a white precipitate on the addition of  $\text{H}_2\text{SO}_4$ .

83. *Galena* [Lead Glance].—*Cubical*.  $\text{H} = 2$  to 2.5;  $\text{G} = 7.5$ ; opaque; lustre metallic; colour lead-grey; streak greyish black. Crystals like figs. 38, 39, 51, 52, 55, 56, 57, etc., with perfect cubical cleavage. Occurs sometimes in radiated or granular masses.

*Comp.*—Anhydrous sulphide of lead,  $\text{PbS}$ . Pure specimens contain nearly 87 per cent. of lead.

*B. etc.*—In closed tube sometimes decrepitates. Yields a yellow sublimate of sulphur, and sometimes a white sublimate of sulphate of lead. On charcoal is easily reduced without soda to a malleable bead of lead. Soluble in  $\text{HNO}_3$ , giving off red nitrous fumes, and leaving a white deposit of sulphur.

*Loc.*—It is the common ore of lead, being abundant in the lead mines of Derbyshire, Cumberland, Wales, and Cornwall. Foreign localities are too numerous to mention.

Galena usually contains a small proportion of silver, varying from two or three to several hundred ounces to the ton of ore. The galenas of Cornwall and Devon contain on an average about 35 oz. per ton.

84. *Cerussite* [White Lead Ore].—*Rhombic*.  $H = 3$  to  $3.5$ ;  $G = 6.5$ ; transparent to opaque; lustre vitreous or pearly; colour white, sometimes yellow or brown, or with a black tarnish; streak white. Crystals like figs. 96, 99, 142, etc., often in bundles of irregularly formed acicular crystals. Macles very common, two rather distinct cleavages. Very brittle.

*Comp.*—Anhydrous carbonate of lead  $\text{PbCO}_3$ , containing 77 per cent. of lead.

*B. etc.*—In open tube no change. Easily reduced to metal if heated on charcoal in  $\text{RF}$ , even if without fluxes. Soluble without effervescence in  $\text{HCl}$ .

*Loc.*—It occurs very commonly in veins or beds with galena, and is particularly abundant in the shallower parts of mines. Very magnificent crystals were obtained at Pentire Glaze Mine in St. Minver, Cornwall, many years ago. Fine specimens occur also at Alston Moor and Keswick in Cumberland, at Leadhills in Scotland, and other localities, both British and foreign.

*Earthy lead ore* is an opaque earthy variety which is very frequently found associated with the crystalline variety.

**85. Anglesite.** — *Rhombic*.  $H = 3$ ;  $G = 6$  to  $6.3$ ; transparent to opaque; lustre adamantine; white, or slightly tinged yellow or brown; streak white. Crystals sometimes like figs. 94, 97, etc., usually small and often in irregular groups.

*Comp.*—Anhydrous sulphate of lead,  $Pb SO_4$ , with nearly 70 per cent. of lead in pure specimens.

*B. etc.*—On charcoal in OF melts to a white globule, in RF is easily reduced to metal without the use of soda. Decomposed by  $HNO_3$ , but slowly and without effervescence, by which reaction it may be readily distinguished from cerussite. More completely soluble in  $KHO$ .

*Loc.*—Fine specimens have occurred at Pary's Mine, Anglesea, at Leadhills in Scotland, and other lead mines in Britain, as well as in some of the foreign mines, but it is rarely found in any great abundance.

**86. Pyromorphite** [Green Lead Ore]. — *Hexagonal*.  $H = 3.5$  to  $4$ ;  $G = 7$ ; translucent to opaque; lustre resinous or vitreous; colour various shades of green, yellow, or brown; streak much lighter than colour. Crystals, like figs. 111, 118, with the planes OP, often rough or hollow.

*Comp.*—Anhydrous phosphate of lead, with some chloride of lead. Formula  $3 Pb_3 (PO_4)_2 + Pb Cl_2$ , resembling the formula of apatite. Pure specimens contain about 76 per cent. of lead.

*B. etc.*—Fuses readily, and on cooling assumes a crystalline form. In RF, with soda, is easily reduced to metal. Soluble in  $HNO_3$  and in  $KHO$ .

*Loc.*—The finest specimens are found at Příbram, Mies, and Bleistadt in Bohemia, but very fine specimens have been obtained from Leadhills in Scotland, Huel Rose and Huel Penrose in Cornwall, and several other British localities.

**87. Miméteite** [Miméteite]. — *Hexagonal*.  $H = 3.5$  to  $4$ ;  $G = 7$ ; translucent to opaque; lustre resinous or vitreous; colour sometimes white, but usually some

shade of yellow or brown, with occasionally a greenish tinge. Crystals like those of pyromorphite.

*Comp.*—Anhydrous arseniate of lead, formula  $3 \text{Pb}_3(\text{AsO}_4)_2 + \text{PbCl}_2$ , resembling those of pyromorphite and apatite. The percentage of lead in pure specimens is about 62 per cent.

*B. etc.*—Like pyromorphite, but not so readily fusible, and gives off arsenical vapours. Soluble in  $\text{HNO}_3$  and  $\text{KHO}$ .

*Loc. and Var.*—Fine specimens have been obtained at Huel Alfred and Huel Unity in Cornwall, Caldbeckfell in Cumberland, and Beeralstone in Devonshire.

*Kampylite* is a variety in which the crystal faces are curved, and which contains a considerable proportion of phosphate of lead. It occurs at Alston in Cumberland.

Pyromorphite is seldom quite free from arsenic, or mimetite from phosphorus. This fact, together with their similarity of composition and of crystalline form, has led several mineralogists to join them into one species.

#### d. IRON GROUP.

Iron ores are generally rather hard and heavy, except the earthy varieties and vivianite. All are more or less magnetic after exposure to RF, while magnetite is usually strongly magnetic in its natural condition. With borax iron ores give a bead which in OF is brown or yellow while hot, and somewhat lighter when cold; in RF a bottle-green bead. All are soluble more or less in  $\text{HNO}_3$ , and yield a blue precipitate (Prussian blue) with yellow prussiate of potash. This latter test, however, is so delicate that a strong blue precipitate is often obtained from the small proportion of iron existing as impurity in other minerals.

**88. Magnetite [Native Loadstone].**—*Cubical*.  $H = 6$ ;  $G = 5$ ; opaque; lustre metallic; colour black or iron grey, sometimes brownish; streak black. Crystals like *Fig.* 38, 39, 40, 51, 52, 53, 134, etc., but seldom large;

sometimes a perfect cleavage parallel to O. Macles not uncommon. Often occurs in large masses, thick beds, or loose grains. Mostly very magnetic.

*Comp.*—Anhydrous proto-peroxide of iron,  $\text{Fe}_2\text{O}_3 + \text{FeO}$ , or more simply  $\text{Fe}_3\text{O}_4$ . Pure specimens contain about 72 per cent. of iron.

*B. etc.*—Infusible; turns brown, and often becomes less magnetic. In closed tube yields no water. Powder more or less completely soluble in H Cl.

*Loc.*—It occurs abundantly in Norway, Sweden, and Russia in thick beds, and in many other foreign countries. Smaller deposits occur at Ilstington in Devon, and at St. Just, Roche, and other places in Cornwall.

Magnetite is frequently found in grains disseminated through basalt, greenstone, serpentine, and other eruptive rocks, which are thus often rendered magnetic. The finest quality of iron is smelted from magnetite.

**89. Hematite** [Red Hematite, Specular Iron, etc.].—*Hexagonal.*  $H = 6$ ;  $G = 5.2$  (in *kidney iron* the  $H$  and  $G$  are lower, and in *red ochre* much lower). Opaque; lustre metallic or sub-metallic, or fracture sometimes silky; colour iron grey or various shades of red; streak red. Crystals rare and somewhat irregular in form, sometimes like figs. 124, 125. It occurs more frequently in radiated masses of concentric layers and with smooth surfaces (*kidney iron*); sometimes earthy (*ochre*).

*Comp.*—Anhydrous peroxide of iron,  $\text{Fe}_2\text{O}_3$ . Pure specimens contain about 70 per cent. of iron.

*B. etc.*—Infusible, but becomes magnetic; yields no water in closed tube; slowly soluble in H Cl, yielding a rich yellow solution.

*Loc. and Var.*—*Specular iron.* This is the crystallized form which is found in brilliant crystals, often iridescent on the surface, and having striated planes, at Elba, St Helena, and the Island of Ascension.

*Micaceous iron* ore occurs in dark shining scales, or scaly masses, at Ilstington, Devon, and many other localities.

*Red iron* froth is still finer, and looks much like the froth from an ochrey pool. No metallic lustre is visible in this variety. *Red ochre* is the extreme form of this variety; it sometimes occurs in beds of considerable extent. It is soft, but heavy.

*Kidney-iron* occurs in radiated masses of reniform surface and concentric structure, or in masses which break with a very peculiar metallic conchoidal fracture. It is a very abundant and valuable ore of iron.

90. **Limonite** [Brown Hematite, etc.]—*Amorphous*.  $H = 5-5.5$ ;  $G = 3.6-4$  (ochrey varieties  $H$  and  $G$  much lower). Opaque; lustre sub-metallic; often silky on fracture; colour iron grey, or various shades of brown; streak brown or brownish yellow; occurs in radiated concretions of reniform exterior, or in cellular or compact masses; sometimes earthy (ochre).

*Comp.*—Hydrated peroxide of iron of somewhat variable composition. The more solid varieties perhaps,  $2 Fe_2 O_3 + 3 H_2 O$ , with iron about 59 per cent.

*B. etc.*—Yields water in closed tube. On  $C$  infusible, but becomes magnetic. Slowly soluble in  $H Cl$ .

*Loc. and Var.*—*Brown hematite* is reniform or compact. The reniform varieties are often called kidney-iron, although quite different from the kidney-iron described under hematite. It is abundant in Cornwall, near Bristol, in Cumberland, and many other localities, British and foreign. It is perhaps the most abundant of the *oxide* ores of iron.

*Wood hematite* has alternate bands of brown or yellow of varied tint, and exhibits a fine radiated structure somewhat resembling wood. It occurs associated with the ordinary brown hematite.

*Stilpnosiderite* is black, or very dark brown, with conchoidal fracture and brilliant lustre. It occurs in very many localities with ordinary limonite.

*Bog iron ore* is soft and loose in texture; often cellular; often found in swampy or marshy districts, in districts where veins of iron ore are situated.



*Yellow ochre* is yellow, earthy, or friable. Fine specimens occur occasionally at Ruby and Knightor mines, near Roche, Cornwall, and in many other localities.

*Brown umber* is brown and earthy. Much of it is brought from the island of Cyprus. Yellow ochre and umber are much used as coarse pigments.

**91. Goethite** [Hydrous oxide of iron].—*Rhombic*.  $H = 5-5.5$ ;  $G = 4-4.4$ . Translucent to opaque; lustre adamantine, silky, sub-metallic or metallic; colour dark red, dark brown, or black; streak yellow or brownish; crystals usually small, but very well formed and brilliant; perfect cleavage. Often occurs in fibrous masses of imperfectly formed crystals.

*Comp.*—Hydrated peroxide of iron,  $Fe_2 H_2 O_4 = Fe_2 O_3 + H_2 O$ . Pure specimens contain 63 per cent. iron.

*B. etc.*—Like limonite, of which it was long, and perhaps rightly, considered a mere variety.

*Loc.*—It occurs with limonite at Restormel, Botallack, and other mines in Cornwall, and in many foreign localities, but it is not nearly so common as limonite. A foliated variety, locally called *rubinglimmer*, occurs at Eiserfeld, near Siegen; the same variety is sometimes found in Cornwall. A capillary form (*Sammel-blende*) occurs at Hüttenberg in Carinthia.

**92. Chalybite** [Spathose Iron Ore, Siderite, etc.]—*Hexagonal*.  $H = 4$ ;  $G = 3.8$ . Transparent to opaque; lustre vitreous or pearly; colours varying from white through yellow, red, brown, to black, darkening on exposure; streak white, or much lighter than the colour; crystals common, but usually small, like figs. 114, 115, 116, 118, 124, 125, 127, 129, etc., with perfect cleavage parallel to R, making angles of  $107^\circ$ .

*Comp.*—Anhydrous carbonate of iron,  $Fe CO_3$ . Pure specimens contain about 42 per cent. of iron.

*B. etc.*—In closed tube gives off no water, but often decrepitates, and always turns black and magnetic; on C the same. Soluble slowly with effervescence in H Cl, especially if warmed.

*Loc. and Var.*—*Sparry iron ore* occurs in beautiful small crystals and crystalline masses in many of the mines of Cornwall, Devon, and Cumberland, but is seldom very abundant. It forms beds of great extent in Styria and Carinthia.

*Clay ironstone* is an earthy variety occurring in beds or layers of nodular concretions in the carboniferous rocks of Britain, Belgium, and Silesia. At present the bulk of the British manufactured iron is obtained from this source. A very great deposit of similar ore occurs in oolitic rocks at Cleveland in Yorkshire.

*Black-band* is a similar variety which contains, besides clay and earthy matter, a considerable proportion of carbon. It is more valuable than the clay ironstone or *clayband*.

*Wood iron* is a fibrous variety occurring at East Pool and other Cornish mines. It must not be mistaken for the wood iron described under limonite.

**93. Pyrites** [Mundic.]—*Cubical*.  $H = 6-6.5$ ;  $G = 4.8-5.1$ . Opaque; lustre metallic; colour usually brassy yellow; streak black; crystals very common, in form resembling figs. 38, 39, 40, 41, 49, 50, 51, 52, 53, 68, etc. No distinct cleavage. Occurs also in radiated or cellular masses.

*Comp.*—Anhydrous di-sulphide of iron,  $FeS_2$ . Pure specimens contain 45.75 per cent. of iron, and 54.25 per cent. of sulphur. Slowly soluble in  $HNO_3$ .

*B. etc.*—In closed tube gives a deposit of sulphur, and turns black. On charcoal fuses readily to a magnetic globule, and burns for a time with blue flame and sulphureous odour. The powder very slowly soluble in  $HNO_3$ .

*Loc.*—It is abundant in almost all mining districts, often occurs in nodules in beds of clay, and is frequently mistaken for gold and copper ore by young or inexperienced miners. It may be readily distinguished from either of these by its superior hardness, both copper ore and gold being easily scratched with a knife.

Pyrites is not worked as an ore of iron but of sulphur, which is used for making sulphuric acid.

**94. Marcasite** [White Iron Pyrites].—*Rhombic*.  $H = 6-6.5$ ;  $G = 4.6-4.9$ . Opaque; lustre, colour, and streak like pyrites. Crystals sometimes like fig. 143. Macles common.

*Comp.*—Like pyrites, from which it scarcely differs except in crystalline form.

*B. etc.*—Like pyrites.

*Loc.*—Sometimes found with pyrites in the Cornish mines, but is especially abundant in the chalk of Folkestone and other places.

**95. Mispickel** [White Mundic].—*Rhombic*.  $H = 5.5-6$ ;  $G = 6$ . Opaque; lustre metallic; colour steel-grey or pale yellow; streak black. Crystals like figs. 86, 89, one distinct cleavage; occurs also radiated and massive.

*Comp.*—Anhydrous sulphide and arsenide of iron,  $FeS_2 + FeAs_2$ , containing 33.5 per cent. of iron, 46.6 per cent. of arsenic, and 19.9 per cent. of sulphur when pure.

*B. etc.*—In closed tube yields first a red then a brown sublimate of sulphide of arsenic, finally a black deposit of metallic arsenic. On charcoal fuses readily to a black metallic globule. Decomposed by  $HNO_3$  and aqua regia, leaving a deposit of sulphur and oxide of arsenic.

*Loc.*—It is exceedingly abundant in the tin mines of Cornwall and Devonshire. It is the source of most of the arsenic of commerce, which is obtained from the mispickel, and the tin ore with which it is mixed, by calcining. The fumes from the calciner are carried along horizontal flues until they condense upon the sides in beautiful crystals. Many specimens of mispickel contain an appreciable amount of silver or gold.

**96. Vivianite.**—*Oblique*.  $H = 2$ ;  $G = 2.6$ . Translucent; lustre vitreous or pearly; colour green, blue, or brown; streak pale blue, speedily turning brown. Crystals rare; one perfect cleavage (clino-diagonal). Thin laminæ flexible but not elastic. Frequently occurs in foliated or earthy masses.

*Comp.*—Hydrated phosphate of iron,  $\text{Fe}_2 (\text{PO}_4)_2 + 8\text{H}_2\text{O}$ .

*B. etc.*—In closed tube yields much water, and turns red or grey. On charcoal fuses readily to a grey shining magnetic globule. Easily soluble in  $\text{HCl}$  or  $\text{HNO}_3$ , turns black in  $\text{KHO}$ .

*Loc. and Var.*—Crystallized vivianite was first discovered at St. Agnes in Cornwall, where very fine crystals were obtained. Fine crystals have also occurred at Huel Jane near Truro, and Huel Edward, St. Just, both in Cornwall. It has since been found in many foreign localities. *Blue iron earth* is a bright blue earthy variety, which often occurs with the crystals.

## c. COBALT GROUP.

Cobalt ores give with borax a deep blue bead in both OF and RF. They are soluble in  $\text{HNO}_3$ , forming a pink solution. They are mostly hard, heavy, and of metallic lustre; but erythrite is soft, light, and has non-metallic lustre.

**97. Smaltite [Tin White Cobalt, Smaltine].**—*Obical.*  $\text{H} = 5.5$ ;  $\text{G} = 6.6$ . Opaque; lustre metallic, generally dull; colour tin-white or steel-grey; streak black. Crystals like pyrites, but very rare. Occurs usually massive, granular, or compact.

*Comp.*—Anhydrous arsenide of cobalt,  $\text{Co As}_2$ , containing, when pure, about 28 per cent. of cobalt.

*B. etc.*—In closed tube a very slight white or reddish sublimate; in open tube a white crystalline sublimate of arsenious anhydride. On charcoal fuses easily, with a strong arsenical odour, to a grey magnetic globule, depositing a thick white incrustation on the support. This residue gives a pure blue colour if heated with borax in both OF and RF. Soluble in  $\text{HNO}_3$ , forming a pink solution.

*Loc.*—It occurs in veins in granite and slate, with ores of silver, cobalt, and tin. It is abundant at Schneeberg

and other places in Saxony, and many other foreign localities, and sometimes occurs at East Pool, Dolcoath, and other mines near Redruth in Cornwall.

**98. Cobaltite** [Cobaltine, Bright White Cobalt].—*Cubical*.  $H = 5.5$ ;  $G = 6$ , the same as smaltite. Opaque; lustre, colour, and streak the same as smaltite, but the colour somewhat whiter and brighter. Crystals like those of pyrites and smaltite, but with perfect cubical cleavage.

*Comp.*—Anhydrous sulphide and arsenide of cobalt,  $Co S_2 + Co As_2$ , the formulae resembling that of mispickel, but with cobalt in place of iron. Pure specimens contain 35.5 per cent. of cobalt, 45.2 of iron, and 19.3 of sulphur.

*B. etc.*—In closed tube a yellow, red, and black sublimate; in open tube a white crystalline sublimate, like mispickel. On charcoal fuses readily to a grey globule, which is generally magnetic. Soluble in  $HNO_3$ , forming a pink solution.

*Loc.*—The finest crystals occur at Skutterud in Norway, Tunaberg in Sweden, and Querbach in Silesia. A few fine crystals were found a few years ago at Botallack Mine, St. Just in Cornwall, but the mineral is never very common.

**99. Erythrite** [Erythrine, Cobalt Bloom].—*Oblique*.  $H = 1.5-2.5$ ;  $G = 3$ . Translucent to opaque; lustre vitreous or pearly; colour and streak usually pink; crystals rare; occurs more often as a thin layer encrusting other cobalt ores, or as an earthy mass.

*Comp.*—Hydrated arseniate of cobalt  $Co_3 (As O_4)_2$  and  $8 H_2 O$ ; like vivianite, but with cobalt in place of iron, and arsenic in place of phosphorus.

*B. etc.*—In closed tube gives off water and turns blue, green, or brown; in open tube deposits a white crystalline sublimate; on C fuses readily to a grey brittle globule, which is mostly magnetic, emitting arsenical fumes, and depositing a white incrustation on the support; turns black if placed in  $K H O$ ; easily soluble in  $HNO_3$ .

*Loc.*—It occurs with other ores of cobalt at Schneeberg and Annaberg in Saxony, and many other localities; crystals are less common than the earthy varieties.

### f. NICKEL GROUP.

Nickel ores are mostly hard and heavy, like those of cobalt; with borax they form a glass, which is in O F violet while hot, and reddish-brown when cold; in R F the bead is grey; soluble in  $\text{H NO}_3$ , forming a green solution.

**100. Chloanthite** [Rammelsbergite, White Nickel].—*Cubical*.  $\text{H} = 5.5$ ;  $\text{G} = 6.5$ ; like smaltite; opaque; colour, lustre, and streak like smaltite; crystals like those of pyrites, but rare.

*Comp.*—Anhydrous arseniate of nickel,  $\text{Ni As}_2$ , containing when pure about 28 per cent. of nickel and 72 of arsenic.

*B. etc.*—In closed and open tube and on charcoal much the same as smaltite; in borax bead shows nickel reaction. Soluble in  $\text{H NO}_3$ , forming a green solution.

*Loc.*—Schneeberg and other places in Saxony, with ores of cobalt.

**101. Niccolite** [Kupfer-Nickel].—*Hexagonal*.  $\text{H} = 5.5$ ;  $\text{G} = 7.5$ . Opaque; lustre metallic; light copper-red with a greyish tarnish; streak brownish-black; crystals very rare, and often misshapen. Occurs generally massive or disseminated through the substance of granite and other crystalline rocks in veins.

*Comp.*—Anhydrous arseniate of nickel,  $\text{Ni As}$ , containing, when pure, 44 per cent. nickel and 56 per cent. arsenic.

*B. etc.*—The same as chloanthite.

*Loc.*—Freiberg, Schneeberg, Annaberg, and other places in Saxony, at Joachimsthal in Bohemia, and many other places with ores of cobalt and nickel. It often much resembles native copper in colour, but may be readily distinguished by its greater hardness.

## g. COPPER GROUP.

Most copper ores yield a bead of metal when heated on charcoal in R F; some need the addition of soda or borax, especially when iron is present. They are seldom hard, ranging from 1 (some specimens of *melaconite*) to 4; the specific gravity varies from 2·2 in *chrysocolla* to 8·5 in native copper. All are soluble more or less readily in H Cl or H NO<sub>3</sub>; forming a blue solution, the tint of which is much deepened by the addition of an excess of ammonia. The acid solution coats any bright piece of iron placed in it with metallic copper. All the ores of copper if powdered and moistened with H Cl, and held in O F, tinge it beautifully blue.

**102. Copper** [Native Copper].—*Cubical*. H = 2·5—3; G = 8·5. Opaque; lustre metallic; colour copper-red; malleable; hackly fracture; crystals like figs. 38, 39, 52, 56, etc., but generally irregular or indistinct.

*Comp.*—Metallic copper, Cu.

*B. etc.*—Melts readily to a malleable red bead; readily soluble in H NO<sub>3</sub>.

*Loc.*—Fine large masses are raised at the Lake Superior mines in North America, associated with native silver. Smaller specimens occur frequently in the copper mines of Cornwall, especially in the neighbourhood of Redruth.

**103. Cuprite** [Ruby Copper Ore, Red Copper Ore, etc.]—*Cubical*. H = 3·5—4; G = 6. Transparent to opaque; lustre adamantine or sub-metallic; colour and streak red of various shades; brittle; crystals frequent, but usually small, like figs. 38, 39, 40, 51 to 57, 135, etc.; cleavage perfect, parallel to O (octahedral); occurs also in compact or earthy masses.

*Comp.*—Anhydrous suboxide of copper Cu<sub>2</sub>O. Pure specimens contain nearly 89 per cent. of copper.

*B. etc.*—In closed tube darkens; on C in R F is readily reduced to a malleable bead of copper; readily soluble in H NO<sub>3</sub>.

*Loc.*—It formerly occurred in abundance at Huel Buller, Huel Basset, Huel Clifford, and other copper mines near Redruth in Cornwall, also at Phoenix Mine near Liskeard. Fine crystals occur at Chéssy, near Lyons in France, Linares in Spain, and many foreign localities.

*Ruby copper ore* is the name given to brilliant crystals.

*Chalcotrichite* or *capillary red oxide* is a fibrous variety, with beautiful metallic-silky lustre.

*Tile ore* is a massive earthy variety, which often contains a considerable proportion of oxide of iron.

The various forms of cuprite are valuable ores of copper, and in some localities very abundant.

**104. Melaconite** [Black Copper Ore].—*Amorphous*.  $H = 1-2$ ;  $G = 5.2$ . Opaque; dull, greyish-black colour; streak greyish-black and shining. Occurs in brittle, earthy masses, which are often soft enough to soil the fingers.

*Comp.*—Anhydrous oxide of copper,  $CuO$ ; but often containing a considerable proportion of oxide of iron, or manganese and siliceous matter. Pure specimens contain about 79 per cent. of copper.

*B. etc.*—Like cuprite.

*Loc.*—It occurs in many copper mines, and was formerly abundant in Huel Clifford, and other mines near Redruth in Cornwall, as well as in some of the Saxon mines.

**105. Malachite** [Green Carbonate of Copper].—*Oblique*.  $H = 3.5-4$ ;  $G = 4$ . Translucent to opaque; lustre vitreous; colour various shades of green, usually mottled, or in concentric layers; streak green, but lighter than the colour. Crystals rare, and usually small. Occurs mostly in botryoidal or reniform masses.

*Comp.*—Hydrated carbonate of copper,  $CuCO_3 + CuH_2O_2$ . Pure specimens contain about 57 per cent. of copper.

*B. etc.*—In closed tube darkens, and gives off water. On charcoal is readily reduced to a metallic bead. Soluble readily with effervescence in  $HCl$ .



*Loc.*—It occurs in small proportions in many of the Cornish copper mines, but the finest masses are brought from Australia and from the Ural Mountains. It is not often sufficiently abundant to be used as an ore of copper, while its beauty is such as to render it valuable as an ornamental stone.

**106. Chessylite** [Blue Carbonate of Copper Azurite].—*Oblique*.  $H = 3.5-4$ ;  $G = 3.8$ . Translucent to opaque; lustre vitreous; colour and streak dark-blue of various shades. Crystals maced, one rather perfect cleavage.

*Comp.*—Hydrated carbonate of copper,  $2 \text{ Cu CO}_3 + \text{Cu H}_2 \text{ O}_2$ . Pure specimens contain about 55 per cent. of copper.

*B. etc.*—Like malachite.

*Loc.*—It is frequently associated in small proportions with the oxides and green carbonate of copper; but the finest crystals are mostly brought from Chessy near Lyons, and Burra-Burra Mine in Australia. It is a very valuable ore of copper, but is seldom very abundant.

**107. Chrysocolla** [Silicate of Copper].—*Amorphous*.  $H = 2-3$ ;  $G = 2.2$ . Translucent to opaque; lustre vitreous or waxy; colour various shades of green or greenish-blue; streak very pale green.

*Comp.*—Hydrated silicate of copper,  $\text{Cu Si O}_3 + 2\text{H}_2 \text{ O}$ . Pure specimens contain about 35 per cent. of copper, but its composition is extremely variable.

*B. etc.*—In closed tube darkens and gives off water. On charcoal turns black, and on addition of soda is reduced to metal. Slowly soluble in  $\text{H Cl}$  without effervescence.

*Loc.*—It occurs frequently in copper mines, but in small proportion. Fine specimens have been obtained from the joints of the Serpentine in the Lizard district of Cornwall. It often much resembles some varieties of malachite, but may be readily distinguished by its inferior hardness and specific gravity, and by the action of  $\text{H Cl}$  upon it.

**108. Chalcocite** [Grey Copper Ore, Vitreous Copper, Redruthite, Copper Glance, etc.].—*Rhombic*.  $H = 2.5-3$ ;

G = 5—6. Opaque; lustre metallic; colour and streak steel-grey. Crystals sometimes like figs. 98 and 138, seldom large, but often brilliant and macled; often occurs in compact masses; sectile, almost malleable.

*Comp.*—Anhydrous sub-sulphide of copper,  $\text{Cu}_2\text{S}$ . Pure specimens contain nearly 80 per cent. of copper.

*B. etc.*—In closed tube gives off a little sulphur; on charcoal colours the flame blue; in OF sputters and fuses easily; in RF is not so easily fused, but yields a bead of copper more easily on adding a little soda.

*Loc.*—Fine specimens occurred formerly at Huel Crenver, Levant, and other mines, and more recently at St. Ives Consols, all in Cornwall. It is a very valuable ore of copper. It is sometimes mistaken for fahlerz, and by beginners for antimonite, galena, and other ores. It may be distinguished from fahlerz by its sectility and grey streak (fahlerz has a brown streak), from galena by the absence of cleavage, from pyrrargyrite by its streak, from argentite and antimonite by its blow-pipe reactions.

**109. Erubescite** [Purple Copper, Horseflesh Ore, Bornite, etc.]—*Cubical*.  $H = 3$ ;  $G = 5$ . Opaque; lustre metallic; purplish-brown colour, often variegated; greyish-black streak; *scratch* purplish. Crystals like figs. 39, 51, 52, etc., but seldom large, often macled; mostly occurs massive or disseminated.

*Comp.*—Anhydrous sulphide of copper and iron,  $3\text{Cu}_2\text{S} + \text{Fe}_2\text{S}_3$ , containing about 55 per cent. of copper.

*B. etc.*—In closed tube like chalcocite; on charcoal fuses easily to a steel-grey magnetic globule, which is brittle, and greyish-red on fracture; with borax and soda yields a bead of copper, decomposed by  $\text{HNO}_3$ , more readily by aqua regia, leaving sulphur.

*Loc.*—Tincroft, Dolcoath, and other Cornish mines; formerly in fine crystals. It occurs also in many foreign localities, and is used as an ore of copper.

**110. Chalcopyrite** [Yellow Copper Ore, Copper Pyrites, etc.]—*Tetragonal*.  $H = 3.5$ —4;  $G = 4.2$ . Opaque;

lustre metallic; colour bright yellow, with sometimes a beautiful red, green, or purple tarnish; streak greenish-black. Crystals sometimes closely resemble fig. 45, more commonly massive and compact, or disseminated, and frequently botryoidal or reniform.

*Comp.*—Anhydrous sulphide of copper and iron,  $\text{Cu}_2\text{S}$ ,  $\text{Fe}_2\text{S}_3 = (\text{Cu Fe})\text{S}_2$ , with 34·5 per cent. of copper when pure.

*B. etc.*—Like erubescite.

*Loc. and Var.*—The great majority of copper mines. The chief varieties of this, the commonest of all the ores of copper, are the following:—

*Peacock ore.*—This is the variety having a brilliant variegated surface. It is sometimes confounded with erubescite, but may be readily distinguished by scratching it deeply. The *scratch* in chalcopyrite is yellow, in erubescite is brown or purplish. It is, or was, common at the Clifford Mines near Redruth, Phoenix Mines, Liskeard, and Devon Great Consols near Tavistock.

*Blistered copper ore* is the botryoidal or reniform variety. Fine specimens have been obtained from many of the Cornish mines.

Chalcopyrite is sometimes mistaken for pyrites, but it may be readily distinguished as follows:—The colour is usually brighter, or more distinctly yellow, than that of pyrites; it is not so hard, being readily scratched with a knife; it is more readily acted upon by  $\text{HNO}_3$ , and if moistened with  $\text{HCl}$  it will change the blow-pipe flame to blue, which is not the case with pyrites. It is sometimes mistaken for gold, but may be readily known by its brittleness, gold being malleable, and by the decomposing action of  $\text{HNO}_3$ , which does not affect gold.

111. *Olivinite* [Wood-Arsenate of Copper, etc.]—

*Rhombic.*  $\text{H} = 3$ ;  $\text{G} = 4\cdot2$  to  $4\cdot6$ ; translucent to opaque; lustre vitreous, resinous, or silky; colour various shades of green, yellow, or brown; streak green or brown, but lighter than colour. Crystals not uncommon, like fig. 97 and other forms, but usually small.

*Comp.*—Hydrated arseniate of copper,  $\text{Cu}_3 (\text{As}_2 \text{O}_4)_2 + \text{Cu H}_2 \text{O}_7$ .

*B. etc.*—In closed tube yields water and turns black; in open tube yields a white sublimate; in forceps fuses easily to a dark brown bead, with crystalline surface when cool. On C deflagrates, gives off arsenical vapours, and yields a bead of copper.

*Loc.*—Fine crystals have been obtained from several of the Cornish mines near Redruth, especially Huel Gorland. It has also occurred at Alston Moor in Cumberland, and in many foreign localities, but never in any great abundance.

**CLASS IV.—MINERALS CONTAINING THE NOBLE METALS, OR THOSE WHOSE OXIDES MAY BE REDUCED BY HEAT ALONE.**

*(Mercury, Silver, Gold, Platinum).*

**GROUP I.—MERCURY.**

**112. Cinnabar.**—*Hexagonal*.  $\text{H} = 2$  to  $2.5$ ;  $\text{G} = 8$ ; translucent to opaque; lustre adamantine or resinous; colour and streak various shades of red, often scarlet-red. Crystals not common, and usually small. Occurs most frequently in compact, granular, or earthy masses.

*Comp.*—Anhydrous sulphide of mercury,  $\text{Hg S}$ , containing, when pure, 86 per cent. of mercury.

*B. etc.*—In open tube sublimes completely if pure, if previously mixed with soda yields metallic mercury. Soluble in aqua regia, but not in  $\text{H Cl}$ ,  $\text{H NO}_3$ , or  $\text{K HO}$ .

*Loc.*—It occurs in beds and veins with native mercury and pyrites. Fine crystals occur in the coal formation of Wolfstein in Bavaria. It has many other localities, the

chief of which are Almaden in Spain, Idria in Carniola, California, Mexico, and Peru.

The mercury, much used in the extraction of gold and silver from their ores by the processes of amalgamation, is partly obtained as native mercury, but chiefly extracted from cinnabar.

## GROUP II.—SILVER.

The minerals in this group easily yield a bead of silver when heated on charcoal, with or without soda. This bead dissolves in  $\text{HNO}_3$ , forming a colourless solution, which yields a white curdy precipitate of chloride of silver on the addition of common salt or  $\text{HCl}$ . The white precipitate is readily soluble in ammonia. They are mostly soft and tolerably heavy.

**113. Silver [Native Silver].—Cubical.**  $\text{H} = 2.5$  to  $3$ ;  $\text{G} = 10.5$  to  $11$ ; opaque; lustre metallic; colour silver white, but often tarnished yellow, red, brown, or black. Malleable; fracture hackly and difficult to obtain. Crystals like figs. 38, 39, 51, 52, etc., but usually small, and often distorted. Very common in mossy or wiry forms, or leaf-like plates; sometimes massive or disseminated.

*Comp.*—Silver containing minute proportions of gold and other metals.

*B. etc.*—Readily fusible to a brilliant white malleable bead.

*Loc.*—It occurs in veins in granite and other crystalline rocks, with calcite, fluor, quartz, and other minerals. Fine specimens have occurred at Andreasberg in the Hartz, Freiberg in Saxony, and many other European localities, but the finest masses have been found in Mexico and Peru. A very large proportion of the silver of commerce is extracted from lead ore, which is seldom entirely free from silver.

**114. Kerate [Kerargyrite, Horn Silver].—Cubical.**  $\text{H} = 1$  to  $1.5$ ;  $\text{G} = 5.5$ ; translucent to opaque; lustre

adamantine, resinous, or waxy; colour grey, bluish, greenish, or brownish; malleable. Crystals often like figs. 38, 39, 51, 52, etc., usually small and macle. Occurs most frequently massive or disseminated.

*Comp.*—Anhydrous chloride of silver,  $\text{Ag Cl}$ , pure specimens containing 75 per cent. of silver.

*B. etc.*—Fuses very easily to a brown bead, and is gradually reduced to silver without the addition of soda. Slowly soluble in ammonia.

*Loc.*—The upper parts of silver veins in primary rocks, or where these are affected by salt springs at greater depths. It occurs with other silver ores at Freiberg in Saxony, and in other parts of the European continent, and also in small quantities in several of the Cornish mines. The finest specimens occur in Mexico and Peru, and have often a greenish colour.

**115. Argentite** [Silver Glance].—*Cubical*.  $H = 2$  to 2.5; opaque; lustre metallic; colour blackish lead-grey; streak dark grey and malleable. Fracture hackly and uneven. Crystals often like figs. 38, 39, 42, 51, 52 to 57, etc., but usually small, uneven, or in macles. Occurs most frequently arborescent or reticulated, in thin crusts, or massive and compact.

*Comp.*—Anhydrous sub-sulphide of silver,  $\text{Ag}_2\text{S}$ . Pure specimens contain nearly 87 per cent. of silver.

*B. etc.*—In closed tube yields a slight sublimate of sulphur. On charcoal fuses readily, and yields a bead of silver without the use of soda. Soluble in strong  $\text{HNO}_3$ , except the sulphur.

*Loc.*—It occurs with other silver ores, chiefly in granite and other crystalline rocks, and in clay slate, at Freiberg and other places in Saxony, at Joachimsthal in Bohemia, Kongsberg in Norway, etc. It is the common silver ore at Guanaxuato and other places in Mexico, and in Peru. It somewhat resembles *chalcocite* and *galena*, but may be readily distinguished by its *malleability* and *blow-pipe reactions*. So malleable is it sometimes that medals have *been struck* from the argentite of some of the Saxon mines.

**116. Stephanite** [Brittle Sulphuret of Silver].—*Rhombic*.  $H = 2$  to  $2.5$ ;  $G = 6.3$ ; opaque; metallic lustre; colour and streak iron-black. Brittle or sectile. Crystals not common, frequently maced. Occurs also massive, disseminated, etc.

*Comp.*—Anhydrous sulphide of silver and antimony,  $6 Ag_2 S + Sb_2 S_3$ , pure specimens containing about 70 per cent. of silver. It generally contains a small proportion of arsenic.

*B. etc.*—In open tube fuses and yields a white or reddish sublimate. On C melts to a dark grey metallic globule, giving off an arsenical or sulphureous odour. In R F, on the addition of soda, yields a bead of silver. Easily decomposed by warm  $HNO_3$ , leaving oxide of antimony and sulphur.

*Loc.*—Freiberg, Schneeberg, and other places in Saxony, Joachimsthal in Bohemia, and other places on the continent, as well as in Mexico and Peru. Small quantities have been found in Huel Duchy and Huel Herland in Cornwall. It may be distinguished from argentite by its brittleness and different blowpipe reactions.

**117. Pyrargyrite** [Dark-red Silver Ore].—*Hexagonal*.  $H = 2$  to  $2.5$ ;  $G = 5.8$ ; translucent to opaque; colour dark red, sometimes almost black; streak bright red; lustre resinous or adamantine. Crystals often like figs. 121, 122. Cleavage rather perfect, parallel to R. Occurs also massive, dendritic, or investing.

*Comp.*—Anhydrous sulphide of silver and antimony,  $3 Ag_2 S + Sb_2 S_3$ , pure specimens containing 59 per cent. of silver.

*B. etc.*—In closed tube gives a slight sublimate. On C fuses easily, with sulphureous odour, and white fumes without arsenical odour, leaving a bead of silver. Decomposed by  $HNO_3$ .

*Loc.*—Andreasberg, Freiberg, and other places in Saxony, and in small quantities formerly in several of the Cornish mines. It also occurs in Mexico and Peru. It is a very valuable ore of silver. It may be distin-

guished from *realgar* by its darker streak and greater specific gravity; from cinnabar and cuprite by its blow-pipe reactions.

**118. Proustite** [Light-red Silver Ore].—*Hexagonal*.  $H = 2$  to  $2.5$ ;  $G = 5.5$ ; translucent to opaque; colour and streak light red; lustre resinous. Crystals frequently like those of pyrargyrite.

*Comp.*—Anhydrous sulphide of silver and arsenic,  $3 Ag_2 S = As_2 S_3$ , the formula resembling that of pyrargyrite, but arsenic substituted for antimony. Contains 65 per cent. of silver when pure.

*B. etc.*—Like pyrargyrite, but gives arsenical reactions.

*Loc.*—Annaberg, Schneeberg, and other places in Saxony.

### GROUP III.—GOLD.

**119. Gold** [Native Gold].—*Cubical*.  $H = 2.5$  to  $3$ ;  $G = 15$  to  $19.4$ ; opaque; lustre metallic; colour pure yellow of various shades; very malleable. Crystals like figs. 38, 39, 40, etc., but very rare. Occurs more frequently in scales or irregularly shaped nodules, or in small grains.

*Comp.*—Sometimes almost perfectly pure, but often combined with small proportions of silver, copper, and other metals.

*B. etc.*—In closed tube unchanged. On  $C$  fuses readily, but is not otherwise changed. Insoluble in  $HCl$  or  $HNO_3$ , but soluble in aqua regia, forming a yellow solution.

*Loc.*—The largest masses or nuggets have been found in Australia and California, generally imbedded in alluvial deposits of sand, or clay, or gravel, called *wash-dirt* by the diggers. Gold is one of the most widely distributed minerals, its localities being exceedingly numerous and in all parts of the world. Small quantities have been found in many parts of the British Isles, especially in the tin-stream works of Cornwall; at North Molton



in Devon; in Caermarthenshire, at the Gogofan mine; in Sutherlandshire, and several other parts of Scotland; and in Wicklow, and other parts of Ireland.

Besides the gold found in quartz rocks and in alluvial deposits, small quantities are extracted from silver, and especially from iron pyrites.

Gold may be readily distinguished from pyrites and chalcopyrite by its malleability, insolubility in  $\text{HCl}$  or  $\text{HNO}_3$ , and by its melting without further change before the blowpipe.

#### GROUP IV.—PLATINUM.

**120. Platinum.**—*Cubical.*  $\text{H} = 4.5$ ;  $\text{G} = 17$  to  $19$ ; opaque; lustre metallic, but often dull; colour steel grey. Malleable. Crystals very rare. Occurs more usually in rounded grains.

*Comp.*—Metallic platinum, usually containing small proportions of iridium, osmium, palladium, and other rare metals.

*B. etc.*—Infusible, except in very minute grains. Insoluble in  $\text{HCl}$  or  $\text{HNO}_3$ ; soluble in aqua regia, but not so readily as gold; forming a red solution.

*Loc.*—It occurs in alluvial deposits in several parts of South America, especially in Columbia and Brazil. It is also found in the Ural Mountains, and in the sands of many of its eastern valleys. To the chemist platinum is of greater value than even gold itself, on account of its great power of resisting the action of acids. The largest piece ever found weighed about 18 lbs., and was found in the Ural Mountains.

## EXAMINATION QUESTIONS.

(The Figures in Brackets refer to the Sections in Parts I. and II. respectively, in which the Answers may be found).

1. State accurately what is meant by a *mineral*, and show the inconvenience of a vague use of the term (i., 1).
2. In what does a *rock* differ from a *mineral* (i., 2)?
3. What are the chief *imitative* forms of minerals (i., 6)?
4. Give a brief account of the six "systems" of crystallography (i., 12).
5. What do you understand by the "axes" of a crystal (i., 9)?
6. Define the triangles called equilateral, isosceles, scalene (i., 10).
7. What essential difference is there between a deltoid and a deltohedron (i., 10, 11).
8. Describe the octahedron, rhombohedron, rhombic dodecahedron, and scalenohedron (i., 11).
9. Define a prism and a pyramid (i., 11).
10. Describe the seven holohedral forms of the cubical system (i., 17 to 23).
11. What do you understand by the terms single and double refraction (i., 109, 110)?
12. Describe some mode of determining the specific gravity of a mineral (i., 99).
13. Give examples of each kind of lustre usually met with in minerals (i., 106).
14. What ten minerals are usually referred to as a standard of hardness? Mention convenient and easily obtained substitutes (i., 93, 96).
15. What minerals possess the property of magnetism (i., 100)?
16. State how colours imparted to borax glass by oxides may be made use of in testing for the presence of certain metals (i., 132).
17. How would you distinguish by their cleavage alone crystals of zinc-blende, rock-salt, and fluorspar? (i., 89).
18. A bead of borax glass is coloured violet by a metallic oxide in the oxidizing flame, and becomes colourless in R.F. What metal is present (i., 132)?
19. State what characteristic appearances are produced by the heating on a piece of charcoal of arsenic, zinc, and lead (i., 129).
20. Explain the principle of the common and the reflecting goniometer (i., 84, 85).
21. What are the hardness and composition of *graphite*, *gypsum*, *apatite*, and *corundum* (ii., 2, 21, 22, 29)?
22. In what way, without the aid of chemicals, would you distinguish between rough pieces of *rock-crystal*, *topaz*, and *diamond* (i., 1, 26, 45)?
23. What are the chief properties of *augite*, *labradorite*, *magnetic iron*, *leucite* (ii., 34, 36, 40, 88)?

24. What percentage of iron is contained in pure specimens of *magnetite*, *specular iron*, *goethite*, and *limonite* (ii., 88, 89, 90, 91)?

25. What are the chief differences of physical characters in the following minerals:—*cassiterite*, *zinc-blende*, *schorl*, *garnet*, and *wolfram*? (ii., 82, 81, 70, 41, 48).

26. Describe the chief mineral compounds of sulphur with copper, lead, zinc, iron, and silver (ii., 81, 83, 93, 94, 108, 109, 110, 115, 116).

27. What are the differences between *calcite* and *aragonite* (ii., 19, 20)?

28. Name five of the most important minerals found *native* or uncombined, and give their specific gravities (ii., 1, 8, 77, 102, 113, 119).

29. Describe fully the minerals *pyromorphite* and *mimetite* (ii., 86, 87).

30. Describe the different varieties of coal, and say whether you regard them as minerals or not, giving reasons for your opinion (i., 1, and ii., 3).

31. Describe the minerals *hornblende*, *garnet*, *axinite*, and *serpentine* (ii., 39, 41, 44, 59).

32. In what minerals does arsenic occur most frequently and in largest proportion (ii., 95, 73, 74)?

33. Describe the chief varieties of *quartz* (ii., 26).

34. Describe the chief forms of *carbonate of lime* (ii., 19).

35. Describe four of the most important ores of lead, and mention the percentage of metal in pure specimens (ii., 83, 84, 85, 86).

36. Describe seven ores of copper, and state the percentage of metal in each (ii., 103, 104, 105, 108, 119, 110, 106).

37. Describe the minerals *barytes* and *fluor* (ii., 16, 23).

38. What minerals are frequently with *cassiterite* (i., 138)?

39. What are pseudomorphous crystals (i., 135)?

40. Give an outline of two different methods of classifying minerals (i., 139 to 144).

41. What are the feldspars? Mention their hardness, specific gravity, chief peculiarities, and modes of occurrence (ii., p. 104).

42. What are the zeolites? Give the chemical composition of four zeolites (ii., 55, 56, 57, 58).

43. How would you proceed to obtain an oxidizing and a reducing flame with the aid of a blowpipe and an oil lamp (i., 124, 125)?

44. What minerals have been adopted as a scale of fusibility (i., 116)?

Besides being exercised with such questions as the above, each student should be frequently made to draw crystals from memory, and from actual specimens, and to experiment upon such minerals as can be obtained for the purpose,

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